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NOTICE OF FEE INCREASE

After 70 years of publication, it has become necessary to change the fee structure that supports *California Fish and Game.* Beginning with the January 1986 issue the individual subscription fee will be increased from $5 to $10 per year. Libraries and institutions providing exchange material to The California Department of Fish and Game will continue receiving the journal on a complimentary basis; those that do not will be charged the increased rate. Additionally, $35 per page will be charged to authors or their institutions. These charges will be assessed on all manuscripts submitted after January 1, 1986. Authors will be billed upon receiving galley proofs for review. Finally, authors will be charged for all reprints. A reprint fee schedule will be provided with the transmittal of galley proof.

The editorial staff does not believe that these charges are high enough to preclude the ability of prospective authors to publish in the journal or of subscribers to obtain it. This income will ensure the continuation and enhancement of the professional reputation the journal currently enjoys.

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TEMPORAL DISTRIBUTION OF BREEDING AND NON-BREEDING CANADA GEESE FROM NORTHEASTERN CALIFORNIA [1]

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During June 1979, red neck collars with individual codes were placed on 999 western Canada geese, *Branta candensis moffitti,* on three molting areas (Goose Lake, Telephone Flat Reservoir, and Meiss Lake) and two nesting areas (Tule Lake NWR and Beeler Reservoir) in northeastern California. During the 4-yr study period, 538 collar sightings from 319 individuals were made and 179 collared geese were reported shot. Fifty-nine percent of marked geese were seen only once compared to 1% seen six times. Most sightings were made on the breeding and wintering grounds of northeastern California (51%) and wintering grounds on municipal water district reservoirs in counties surrounding San Francisco Bay (43%). San Pablo Dam Reservoir is the wintering area most used by Goose Lake and Telephone Flat Reservoir geese. Goose Lake and Telephone Flat Reservoir geese utilized some of the same reservoirs in the Bay Area, but did so in different proportions. The reservoirs are closed to hunting and consequently geese wintering there have less hunting pressure compared to those remaining in northeastern California. Meiss Lake and Tule Lake flocks were semi-resident and seldom left northeastern California. Tule Lake geese sustained a greater harvest than geese from the three molting areas. Some one- and two-yr old geese made a molt migration to the Northwest Territories. A few geese wintered as far south as the San Joaquin Valley where they overlapped with the Rocky Mountain population.

INTRODUCTION

The western Canada goose of the Pacific Flyway currently is regarded as consisting of two main populations, the Pacific and the Rocky Mountain (Krohn and Bizeau 1980). The Pacific population is comprised of five subpopulations, one of which includes northeastern California along with southeastern Oregon and northwestern Nevada. California Department of Fish and Game and U.S. Fish and Wildlife Service biologists estimate the average population size of Canada geese breeding in California at approximately 20,000.

During 10 days in mid-June 1979, 999 Canada geese were marked with red neck collars on the breeding grounds of northeastern California. Each collar was inscribed with a black letter "k" and three black digits oriented vertically and repeated four times. Raveling (1978) suggested and Krohn and Bizeau (1980) concurred that serious consideration be given to exchanging routine agency banding programs for color marking programs and to the assignment of a biologist to "live" with each population subunit of interest to obtain consistency in records of marked individuals. Use of collars has generally been acknowledged as the best technique for studying geese.

Objectives of the study were to (i) relate nesting areas of northeastern California with molting areas, (ii) to relate breeding areas with wintering areas, and (iii) to locate the boundary in the Central Valley of California between the wintering areas of the Pacific and Rocky Mountain populations of Canada geese.

[1] Accepted for publication January 1985.

METHODS

Flightless geese were captured by herding with boats into a corral-type trap set on shore. Usually, the goose drive started 3–13 km from the trap site and covered a wide area. The operation was directed by airplane with radio communication to boats. About 15 persons were recruited from California Department of Fish and Game, U.S. Fish and Wildlife Service, U.S. Forest Service, and University of California-Davis to trap and collar geese.

The plan was to collar 500 geese on nesting areas of Tule Lake NWR and Beeler Reservoir and 500 on molting areas of Goose Lake, Telephone Flat Reservoir and Meiss Lake (Figure 1). However, fewer geese were caught on nesting areas than expected, so more geese were collared on the molting areas. (Table 1).

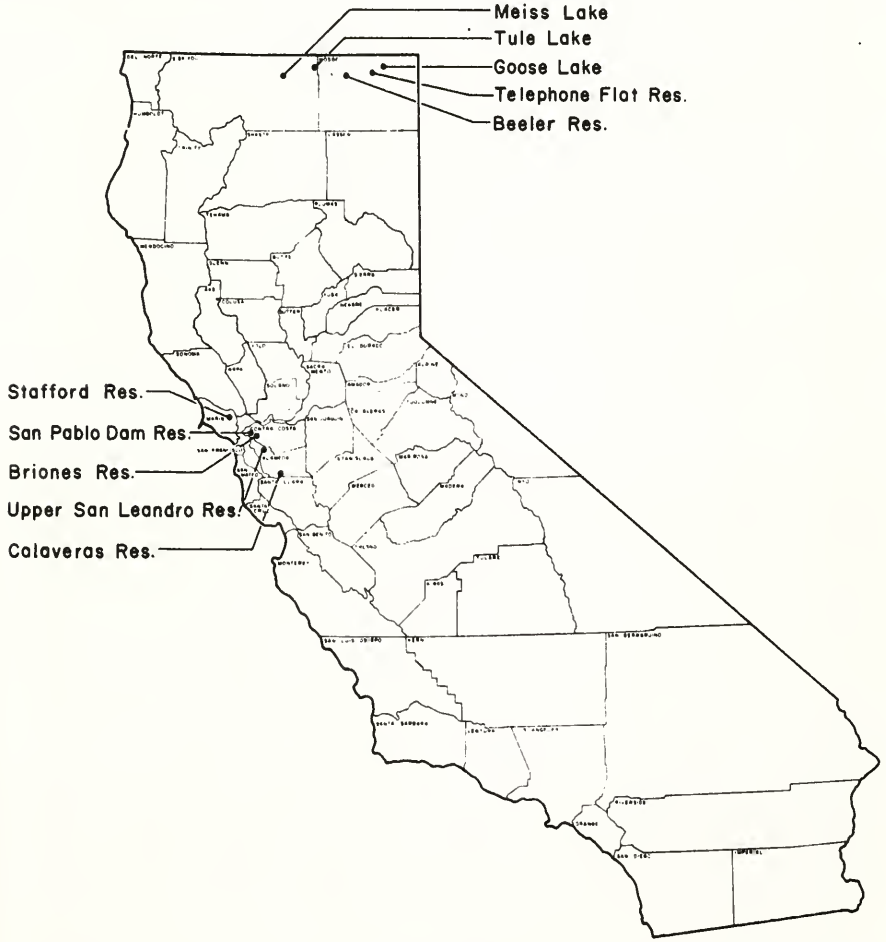

FIGURE 1. Locations of banding sites of Canada geese in northeastern California and wintering areas of Canada geese in the San Francisco Bay Area.

TABLE 1. Number of Canada Geese Collared in Northeastern California, June 1979, and Number Subsequently Sighted or Shot.

Collaring Site	*Collared Adult*	*Collared Local*	*Total*	*Individuals sighted (%)*	*Number sightings* [a]	*Number shot* [b]
Goose Lake	300	–	300	85(28)	136	51
Telephone Flat Res.	323	–	323	124(38)	211	55
Meiss Lake	150	–	150	18(12)	25	20
Beeler Res.	10	17	27	7(26)	16	5
Tule Lake NWR	109	90	199	85(43)	150	48
Total	892	107	999	319	538	179

[a] Some individuals sighted several times.
[b] As of January 31, 1983.

In the first year after trapping (October 1979–May 1980), all known and potential goose areas in California from Merced County (see Figure 1) north were searched at least once for collared geese (Table 2).

TABLE 2. Distribution by Days of Effort Expended in Searching for Neck-banded Canada Geese in California, 1979–82.*

Location	*MONTH* S	O	N	D	J	F	M	A	M	J	J	A	*Total*
Klamath Basin													
1979		9	7										16
1980	2	2	2							7	7		20
1981	7	5	1				1		3				17
1982	1	1	2		2				2				8
Northeastern Calif.													
1979													
1980						3			9	1			13
1981									6				6
1982							1		9				10
Shasta and Scott Valleys													
1979				1									1
1980						2			4				6
1981									2				2
1982													
Sacramento Valley													
1979			2	5	4								11
1980				1	1								2
1981					1								1
1982					3	1							4
San Francisco Bay Area													
1979				4									4
1980				5	11	2							18
1981				4	4								8
1982					4								4
North San Joaquin Valley+													
1979				16									16
1980				13	26	24	5						68
1981			1	11	18	16	3						49
1982			1	13	34	24	16						88
Warner Valley, Oregon													
1980									2				2

* Includes sightings from all major contributors
+ Major portion of observation time was made by Aleutian Canada goose observation team while searching for Aleutian geese.

RESULTS AND DISCUSSION

Between October 1979 and March 1983, 538 collar sightings were made from 319 individually marked geese. During the same time, 179 collared geese were reported shot (Table 1). Forty-one percent of the sightings were made the first year, 34% the second year and 21% during the third year. Although no search effort was made, 4% were seen in the fourth year. Fifty-nine percent of the geese sighted were seen only once during the study (Table 3). Forty-six percent were seen at least once and/or shot. Eighty percent of the shot geese were never seen alive after collaring.

TABLE 3. Sightings Per Individual Collared Canada Goose in California, 1979–82.

Sightings	*Percent*
1	59
2	21
3	11
4	6
5	2
6	1
	100

Although much of the northern half of California was searched for marked geese the first year, most of the observations of the 319 marked geese were made on the breeding and wintering grounds of northeastern California (51%) and on the wintering grounds in the San Francisco Bay Area (41%).

Whereas the number of sightings per area can be regarded as somewhat representative of the distribution of the population, it mainly indicates where emphasis was placed in searching for collars (Table 2). For example, more hours of searching were spent in the Klamath Basin throughout spring, summer and fall compared to the relatively short time spent searching in the San Francisco Bay Area during winter, yet 43% of the 538 sightings came from the Bay Area compared to 38% from the Klamath Basin. However, the number of geese collared on each of the five banding areas has an influence on these percentages. For example, approximately two-thirds (623) of the 999 geese marked were from Goose Lake and Telephone Flat Reservoir, and the Bay Area is the main wintering ground for these birds. The fact that less than one-half of the collared geese were observed in the field is assumed to be the result of limited time available for searching for marked geese.

San Francisco Bay Area

Leg band recoveries indicate that most geese migrating south from northeastern California disperse throughout the Sacramento Valley (W. Rienecker, Calif. Dept. Fish and Game, unpubl. rep.). However, this is only indicated from harvested geese. The majority of collars sighted during the winter were seen on municipal water district reservoirs in counties surrounding San Francisco Bay. These reservoirs are closed to hunting and therefore not sampled by hunter kill. The importance of these reservoirs as a wintering area for northeastern California Canada geese was not well known prior to this study.

Collar sightings supported by leg band recovery data (W. Rienecker, Calif. Dept. Fish and Game, unpubl. rep.) suggest that geese from all five collar areas could conceivably be found on one reservoir at some time during winter, but

not necessarily at the same time. Although some geese were seen more than once on an area, suggesting they might have stayed there for the winter, others were seen only once suggesting that some geese are more mobile, or that sightings were not made at the final destination of the wintering grounds.

Although geese collared at Goose Lake and Telephone Flat Reservoir utilized some of the same reservoirs in the San Francisco Bay Area, they did so in different proportions (Table 4). For example, 66% of the Telephone Flat Reservoir geese were seen at San Pablo Dam Reservoir, and 27% at Upper San Leandro Reservoir; compared to 38% and 13% respectively, for geese marked at Goose Lake.

It was common to see a Telephone Flat Reservoir goose on San Pablo Dam Reservoir one winter, and again a few weeks later or the following year on Upper San Leandro Reservoir, 45 km apart. This suggests that a preferred wintering area might encompass two or more water areas, possibly due to feed conditions or harassment.

For Goose Lake and Telephone Flat Reservoir geese, the San Francisco Bay Area is the most important wintering area south of northeastern California. San Pablo Dam Reservoir appears to have the greatest goose use. Once having reached 2 years of age, most Canada geese continued to return to their traditional roost sites in subsequent years (Raveling 1979). Crissey (1968) stated that during the migration and wintering periods about all that Canada geese seem to require is a pond of water five or more acres in size, free from disturbance and surrounded by agricultural land where birds can either graze or feed on waste grain. San Francisco Bay Area reservoirs meet these requirements. Each reservoir is at least several hundred acres with ample grazing on surrounding hillsides. These reservoirs are closed to hunting and have restricted public use which is, no doubt, an added attraction to geese. Rienecker's study on Canada geese leg-banded in northeastern California (Calif. Dept. Fish and Game, unpubl. rep.) indicate nonbreeding geese banded on the molting areas of Goose Lake and Clear Lake had a lower band recovery rate than breeding adults banded on the nesting grounds. He assumed this discrepancy was caused by nonbreeders inhabiting areas with less hunting pressure than areas occupied by breeders. These data suggest that the San Francisco Bay Area reservoirs are the areas of less hunting pressure. Raveling (1978) indicated that a breeding population can show expansion because of favorable survival of a large subunit while other subunits are unknowingly being extirpated.

Relationship Between Nesting and Molting Areas

Goose Lake

Prior to this study, the assumption was that some molters on Goose Lake came from nesting areas in Oregon (e.g. the Warner Valley), but the absence of collar sightings from Oregon suggest these geese are not generally found north of Goose Lake (Table 5). Retrap data (W. Rienecker, Calif. Dept. Fish and Game, unpubl. rep.) from leg-banded geese and the lack of collar sightings in Surprise Valley, California also suggest they do not come from nesting areas east of Goose Lake. All sightings during the breeding period were from the south and southwest of Goose Lake along the Pit River drainage as far as Big Valley, and from the reservoirs to the west in the Devil's Garden of Modoc National Forest. Spring sightings on the Modoc NWR, south of Goose Lake, were dominated by Goose Lake birds.

TABLE 4. Canada Goose Collar Sightings on San Francisco Bay Area Reservoirs, 1979–82.*

	Collaring area							
	Goose Lake				*Telephone Flat Res.*			
Sight area	*1979–80*	*1980–81*	*1981–82*	*Total (%)*	*1979–80*	*1980–81*	*1981–82*	*Total (%)*
San Pablo Dam Reservoir	14	5	2	21(38)	39	21	16	76(66)
Upper San Leandro Reservoir	3	3	1	7(13)	9	18	4	31(27)
Briones Reservoir	3	6	5	14(26)	1	1	–	2(2)
Calaveras Reservoir	4	1	4	9(16)	–	–	–	–
Stafford Reservoir	1	3	–	4(7)	3	3	–	6(5)
Total	25	17	12	55(100)	52	43	20	115(100)

* Using only one sighting per bird per area per year.

TABLE 5. Distribution by Month of 300 Canada Geese Marked at Goose Lake and Observed at Various Locations from October 1979 Through March 1983. [a]

Location	Month of Observation [b] S	O	N	D	J	F	M	A	M	J	J	A	Individuals [c]	Total Sgts [d]	Shot [e]
Northeastern California															
Devil's Garden (Modoc Forest)		x	x	x	x				x				11(11.7) [f]	18(13.2)	11(21.6)
Klamath Basin	x	x	x	x									13(13.8)	13(9.6)	3(5.9)
Big Valley to Burney			x	x	x				x				1(1.1)	1(0.7)	10(19.6)
Alturas to Camby		x	x	x	x			x	x				12(12.8)	13(9.6)	16(31.4)
Surprise Valley					x										2(3.9)
Eagle Lake to Honey Lake				x									1(1.1)		1(2.0)
Sacramento Valley			x	x	x								4(4.3)	5(3.7)	3(5.9)
San Francisco Bay Area															
Stafford Res.				x	x								4(4.3)	5(3.7)	
San Pablo Dam Res.			x	x	x								18(19.1)	34(25.0)	
Briones Res.				x	x								10(10.6)	20(14.7)	
Upper San Leandro Res.				x	x								7(7.4)	10(7.4)	
Alameda Golf Course				x	x								1(1.1)	4(2.9)	
Calaveras Res.				x	x								9(9.6)	10(7.4)	
Misc.				x											2(3.9)
San Joaquin Valley				x	x								2(2.1)	2(1.5)	
Out of State															
Reno, Nevada		x											1(1.1)	1(0.7)	
Oregon					x										1(2.0)
Idaho			x												1(2.0)
Area Unknown															1(2.0)
Total													94(100.1)	136(100.1)	51(100.2)

[a] Includes geese shot.
[b] Each marked month represents one or more observations and/or shot geese.
[c] Some individuals were seen on more than one area.
[d] Total sightings.
[e] Additional to sightings.
[f] Percent.

Telephone Flat Reservoir

Geese from Telephone Flat Reservoir were distributed in a pattern similar to those of Goose Lake but tended more towards the southwest in the direction of Big Valley (Table 6). Some sightings were made as far west as Tule Lake. Five of the 29 sightings of Telephone Flat Reservoir geese made at Tule Lake were recorded during the breeding season.

Meiss Lake

The few sightings made of Meiss Lake birds suggest their nesting areas are located southwest in Shasta and Scott valleys, east to the west side of Lower Klamath NWR, and north to the Klamath Wildlife Area near Klamath Falls, Oregon (Table 7).

Beeler Reservoir

Geese collared on the nesting area of Beeler Reservoir were not found nesting elsewhere. Generally, Beeler Reservoir geese move by late September. Data suggest that some move north to the Klamath Basin in late summer and are apt to stay there until the following breeding season. Others stay in northeastern California until late fall, then move down to the San Francisco Bay Area for the winter (Table 8). Retrap data (W. Rienecker, Calif. Fish and Game, unpubl. rep.) suggest that the non-breeders molt on Clear Lake, 32 km northeast of Beeler Reservoir.

Tule Lake

Tule Lake NWR collared geese were not observed nesting on other areas. For example, although the Lower Klamath NWR is located less than 9.5 km west of Tule Lake, no Tule Lake collared geese were seen nesting there.

The relatively few sightings of Tule Lake geese outside of the Klamath Basin (Table 9) suggest this flock is also semi-resident. Clear Lake, 23 km east of Tule Lake, is the main molting area for these geese; however, each year a segment of non-breeders from this flock migrate to the Northwest Territories to molt (W. Rienecker, Calif. Dept. Fish and Game, unpubl. rep.). The one collar sighted and two collared geese shot in Alberta from the Tule Lake birds (Table 9), plus one shot from the Telephone Flat Reservoir geese were assumed to be returning from the Northwest Territories to California. Sterling and Dzubin (1967) documented molt migration of *B. c. maxima* and *B. c. moffitti* from their midcontinent breeding ranges to the subarctic tundras of the Northwest Territories. Molt migrations have since been documented for the Pacific Canada goose in Oregon (McLaury, Malheur NWR, unpubl. rep.) and Washington (Hanson and Eberhardt 1971) in addition to California (W. Rienecker, Calif. Dept. Fish and Game, unpubl. rep.).

Rienecker (Calif. Dept. Fish and Game, unpubl. rep.) indicated that, according to the breeding ground surveys over the past 20 years, the Klamath Basin Canada goose flock has been in a downward trend, whereas in the remainder of northeastern California, the population has been increasing. He suggested several possibilities for this decline, one of which was overharvest to the point of reducing the breeding population. Although there were no statistically significant differences ($X^2 = 1.2$, $P < .05$) between molting areas in number of geese shot, there was a difference ($X^2 = 3.04$, $P < .10$) between molting areas and the Tule Lake nesting area. Tule Lake adult geese sustained a greater harvest than geese from the three molting areas.

TABLE 6. Distribution by Month of 323 Canada Geese Marked at Telephone Flat Reservoir and Observed at Various Locations from October 1979 Through March 1983.[a]

Location	Month of Observation[b] S	O	N	D	J	F	M	A	M	J	J	A	Individuals[c]	Total Sgts[d]	Shot[e]
Northeastern California															
Devil's Garden (Modoc Forest)		x						x	x				15(9.9)[f]	16(7.6)	5(9.1)
Klamath Basin	x	x		x				x	x				18(11.9)	29(13.7)	6(10.9)
Big Valley to Burney		x	x	x	x		x	x	x				8(5.3)	9(4.3)	12(21.8)
Alturas to Camby		x	x	x		x			x				8(5.3)	9(4.3)	17(30.9)
Surprise Valley															1(1.8)
Eagle Lake to Honey Lake				x	x										3(5.5)
Sacramento Valley				x	x								4(2.6)	4(1.9)	8(14.5)
San Francisco Bay Area		x													
Stafford Res.				x	x								5(3.3)	10(4.7)	
San Pablo Dam Res.			x	x	x								56(37.1)	80(37.9)	
Briones Res.				x	x								3(2.0)	3(1.4)	
Upper San Leandro Res.				x	x								26(17.2)	38(18.0)	
Alameda Golf Course					x								1(0.7)	2(0.9)	
Misc.						x							1(0.7)	2(0.9)	
San Joaquin Valley				x	x								5(3.3)	8(3.8)	
Misc.				x	x										2(3.6)
Out of State															
Alberta, Canada	x														1(1.8)
Oregon											x		1(0.7)	1(0.5)	
Total													151(100.0)	211(99.9)	55(99.9)

[a] Includes geese shot.
[b] Each marked month represents one or more observations and/or shot geese.
[c] Some individuals were seen on more than one area.
[d] Total sightings.
[e] Additional to sightings.
[f] Percent.

TABLE 7. Distribution by Month of 150 Canada Geese Marked at Meiss Lake and Observed at Various Locations from October 1979 Through March 1983. [a]

Location	Month of Observation [b]												Individuals [c]	Total Sgts [d]	Shot [e]
	S	O	N	D	J	F	M	A	M	J	J	A			
Northeastern California															
Klamath Basin	x	x	x	x	x	x	x	x	x				12(66.7) [f]	19(76.0)	9(45.0)
Big Valley to Burney				x											1(5.0)
Shasta and Scott Valleys		x	x	x	x				x				6(33.3)	6(24.0)	10(50.0)
Total													18(100.0)	25(100.0)	20(100.0)

[a] Includes geese shot.
[b] Each marked month represents one or more observations and/or shot geese.
[c] Some individuals were seen on more than one area.
[d] Total sightings.
[e] Additional to sightings.
[f] Percent.

TABLE 8. Distribution of 27 Canada Geese Marked at Beeler Reservoir and Observed at Various Locations from October 1979 Through March 1983. [a]

Location	Month of Observation [b]												Individuals [c]	Total Sgts [d]	Shot [e]
	S	O	N	D	J	F	M	A	M	J	J	A			
Northeastern California															
Devil's Garden (Modoc Forest)									x				3(27.3)[f]	5(31.3)	
Klamath Basin	x	x	x		x								3(27.3)	4(25.0)	3(60.0)
Alturas to Camby					x								1(9.1)	1(6.3)	
Sacramento Valley		x													1(20.0)
San Francisco Bay Area															
Stafford Res.				x	x								2(18.2)	4(25.0)	
Upper San Leandro Res.				x	x								2(18.2)	2(12.5)	
Misc.					x										1(20.0)
Total													11(100.1)	16(100.1)	5(100.0)

[a] Includes geese shot.
[b] Each marked month represents one or more observations and/or shot geese.
[c] Some individuals were seen on more than one area.
[d] Total sightings.
[e] Additional to sightings.
[f] Percent.

TABLE 9. Distribution of 199 Canada Geese Marked at Tule Lake and Observed at Various Locations from October 1979 Through March 1983. [a]

Location	Month of Observation [b]												Individuals [c]	Total Sgts [d]	Shot [e]
	S	O	N	D	J	F	M	A	M	J	J	A			
Northeastern California															
Devil's Garden (Modoc Forest)			x										1(1.1) [f]	1(0.7)	
Klamath Basin	x	x	x	x	x	x		x	x	x	x		78(86.7)	138(92.0)	40(83.3)
Big Valley to Burney		x											1(1.1)	1(0.7)	
Alturas to Camby		x			x										2(4.2)
San Francisco Bay Area															
Stafford Reservoir					x								6(6.7)	6(4.0)	
Out of State															
Alberta, Canada	x	x											1(1.1)	1(0.7)	2(4.2)
Oregon			x												2(4.2)
Denver, Colorado				x									1(1.1)	1(0.7)	
Washoe Lake, Nevada		x					x						2(2.2)	2(1.3)	1(2.1)
Area Unknown		x													1(2.1)
Total													90(100.0)	150(100.1)	48(100.1)

[a] Includes geese shot.
[b] Each marked month represents one or more observations and/or shot geese.
[c] Some individuals were seen on more than one area.
[d] Total sightings.
[e] Additional to sightings.
[f] Percent.

Fall and Winter Movements

There is some uncertainty how much time the various flocks of the northeastern California subpopulation spend on wintering grounds away from the northeastern part of the State. Generally, the first collared geese seen in the San Francisco Bay Area were during the first week in November and the last collar in the second week of February. However, it is suspected that many geese do not migrate as far south as the Bay Area or, if they do, they stay for only a short period of time. Ray Johnson (Klamath Wildl. Area, pers. comm.) stated that geese on his area in the Klamath Basin do not leave for much more than two weeks during winter. A rancher in Fall River Valley stated (pers. comm.) that geese leave the valley only when snow covers their food supply, but return when food is available. This is not a heavy snow area, consequently, food is available most of the winter. However, collar slightings suggest that many nonbreeders and unsuccessful breeders from Goose Lake and Telephone Flat Reservoir move down to central California, especially the San Francisco Bay Area, in the fall and remain there most of the winter.

The distance between breeding area and winter area for Meiss Lake geese is short to nonexistent as compared to the distance traveled by Goose Lake and Telephone Flat Reservoir geese. Few winter south of Shasta Valley suggesting they are more resident than geese on Goose Lake and Telephone Flat Reservoir.

Although the sample was small, Beeler Reservoir geese seem to follow the same pattern as those of Goose Lake and Telephone Flat Reservoir. Six of 27 collared Beeler Reservoir birds were sighted or shot outside northeastern California. The Tule Lake birds, being semiresident, generally leave only if forced out by adverse weather conditions.

Leg band recoveries suggest that the boundary in California between wintering flocks of the Rocky Mountain population and the Pacific population is in the northern San Joaquin Valley. It was thought that the collaring program would be more specific for location of this dividing line between the two populations. However, it appears that very few collared geese wintered in the San Joaquin Valley and there is a gradual thinning out and overlap of the population as they approach the outer limits of their wintering areas.

Problems Associated With Color Marking

The poor color combination of black on red combined with a vertical code of four symbols (letter K and 3 digits) was a distinct hindrance to this study. The code was unnecessarily long and thus too small to be easily read with the average 20–45 power scope. The poor color contrast and small code size on days with poor light conditions and distant geese often resulted in unread codes. Those people that saw geese with collars, but who were not actively searching for collars, were able to read only 36% (62) of the codes on collars. Personnel on this study, however, were equipped with the higher powered Questar scope which improved the success ratio to 73% (474). The Questar was necessary most of the time, but not all codes were read without difficulty. A great deal of time was wasted attempting to read distant collars. Had the codes been larger and more easily read, more time could have been spent searching for other collared geese.

ACKNOWLEDGMENTS

I wish to thank B. Deuel for his assistance on the project, and also C. Ely, J. Johnson and members of the Aleutian Canada goose observation team for recording collar sightings. Appreciation is also extended to D. Raveling and D. Connelly for their critical reviews of this manuscript. Finally, I thank the many people who helped with trapping and collaring. This work was performed as part of Pittman-Robertson Project W-30-R "Waterfowl Studies" supported by Federal Aid to Wildlife Restoration funds.

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THE OCCURRENCE, SEASONAL DISTRIBUTION, AND REPRODUCTIVE CONDITION OF ELASMOBRANCH FISHES IN ELKHORN SLOUGH, CALIFORNIA [1]

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The occurrence, seasonal distribution, and reproductive condition of elasmobranch fishes were studied in Elkhorn Slough, a shallow estuary near Moss Landing, California, from 1 October 1971 through September 1972. Seven species of elasmobranch fishes were captured. In order of abundance they were: leopard shark, *Triakis semifasciata;* bat ray, *Myliobatis californica;* gray smoothhound, *Mustelus californicus;* round stingray, *Urolophus halleri;* shovelnose guitarfish, *Rhinobatos productus;* brown smoothhound, *Mustelus henlei;* and thornback, *Platyrhinoidis triseriata.* Leopard sharks and bat rays were commonly captured in Elkhorn Slough throughout the entire year. Gray smoothhounds, round stingrays, shovelnose guitarfish, and brown smoothhounds were only seasonally common at the study site. Thornbacks were rare at the study site during all seasons. Of the elasmobranch fishes captured in Elkhorn Slough, leopard sharks and bat rays were apparently the only species that regularly gave birth to young in the slough.

INTRODUCTION

Little is known about the seasonal distribution or reproductive biology of elasmobranch fishes along the California Coast. Moreover, the data available on most species are insufficient to even determine if populations are sedentary or migratory. The only published reports on the occurrence and reproductive condition of elasmobranchs in Elkhorn Slough, an estuary in central California, are based on results of annual shark derbies usually held during the months of May and June (Herald and Dempster 1952, Herald 1953, Herald et al. 1960). There are no published reports on the occurrence or reproductive condition of elasmobranchs in Elkhorn Slough during other parts of the year.

There is a need to evaluate the importance of estuaries to the life histories of elasmobranch fishes because these areas are being rapidly lost worldwide due to industrial development. In particular, the value of Elkhorn Slough to elasmobranch fishes must be determined because it is possible that parts of the slough will be developed for industrial and recreational purposes in the future.

The objectives of this paper are to describe the elasmobranch fishes captured in Elkhorn Slough, to present information on their seasonal distribution in the study area, and to describe the reproductive condition of female elasmobranchs captured during the project.

MATERIALS AND METHODS

This study was conducted in Elkhorn Slough (Figure 1), a shallow estuary, located on the east side of Monterey Bay near Moss Landing, California. Elkhorn Slough consists of about 1000 ha of submerged areas, tidal flats and salt marsh. The slough has a maximum depth of approximately 4 to 5 meters and is characterized by extensive mudflats that are periodically exposed during low tide and

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inundated during high tide. A more detailed description of the study area was presented by Talent (1976); Browning (1972) provided a thorough description of Elkhorn Slough and the surrounding area.

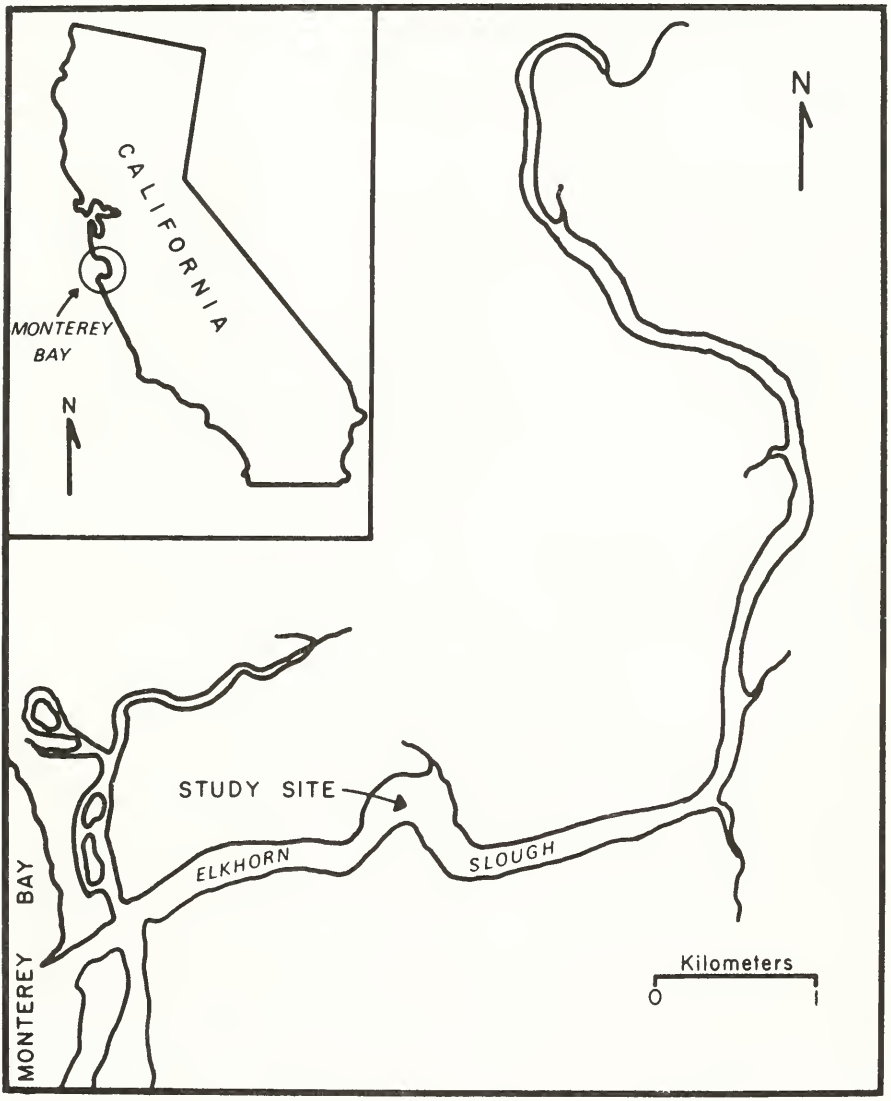

FIGURE 1. Map of Elkhorn Slough showing the study site.

Results of this paper are based on elasmobranch fishes collected from 1 October 1971 through September 1972. Elasmobranchs were collected at least monthly with two 90-m nylon gill nets that contained longitudinal sections of 10.2, 15.2, and 22.9-cm stretch mesh, 30 m each. Mesh sizes smaller than 10.2-cm stretch were not used in order to minimize the capture of large numbers of bony fishes. All gill net sets were on the bottom, 2.4 km from the mouth of Elkhorn Slough (Figure 1).

Gill nets were set perpendicular to water flow in the slough 1 or 2 hours before sunset and fished overnight. When nets were retrieved (early morning), water temperature was determined at the surface and near the bottom with a bucket thermometer. Water samples were then taken from the surface and bottom with Niskin bottles and were later analyzed for salinity with a Kahlisco precision induction salinometer. Salinity was computed from conductivity ratios using the equations of Cox, Culkin, and Riley (1967).

All captured elasmobranchs were measured to the nearest millimetre. Total length (TL) of all elasmobranchs except rays was measured; for rays disc width (DW) was measured. The sex of all fishes was determined and the reproductive condition of females was determined by necropsy.

The relative abundance of all sizes of all species of elasmobranchs in Elkhorn Slough could not be evaluated due to the size and species selectivity bias of the gill nets. Sharks less than 40 cm TL, for example, were too small to be captured by the smallest mesh netting used. Although bat rays and round stingrays were captured, they usually were not captured unless their caudal sting became entangled in the netting. Thus, capture results do not necessarily represent the relative abundance of the different species in Elkhorn Slough. Also, information obtained on the abundance and species of elasmobranchs in Elkhorn Slough during summer was limited because green algae, *Enteromorpha* spp., grew profusely in Elkhorn Slough. As a result, drifting algae completely fouled the gill nets during June and July preventing capture of elasmobranchs.

To facilitate seasonal comparisons of elasmobranch abundance, the year was divided as follows: winter (Nov., Dec., Jan.); spring (Feb., March, April); summer (May, June, July); and fall (Aug., Sept., Oct.).

RESULTS

Temperature and Salinity

The water at the study site was well mixed during all collection periods. Wilcoxon matched-pairs sign-ranks tests (Siegel 1956) indicated there was no significant difference between the surface and bottom water temperature ($P > .05$) or the surface and bottom salinity ($P > .05$). There were, however, seasonal differences in water temperature and salinity (Figure 2). The monthly averages of surface and bottom water temperature were low (below 12°C) during winter and early spring but high (above 14°C) during most other parts of the year.

Except for November, the monthly averages of surface and bottom salinity were not significantly different from water in Monterey Bay ($P > .05$) and ranged from 32.7 to 33.6 ‰. During November, as a result of heavy rainfall, the monthly average surface and bottom salinity decreased to 30.9 ‰.

Species Accounts

Seven species of elasmobranch fishes were captured in Elkhorn Slough. These, listed in order of total number captured, were the leopard shark, *Triakis semifasciata;* bat ray, *Myliobatis californica;* gray smoothhound, *Mustelus californicus;* round stingray, *Urolophus halleri;* shovelnose guitarfish, *Rhinobatos productus;* brown smoothhound, *Mustelus henlei;* and thornback, *Platyrhinoidis triseriata.*

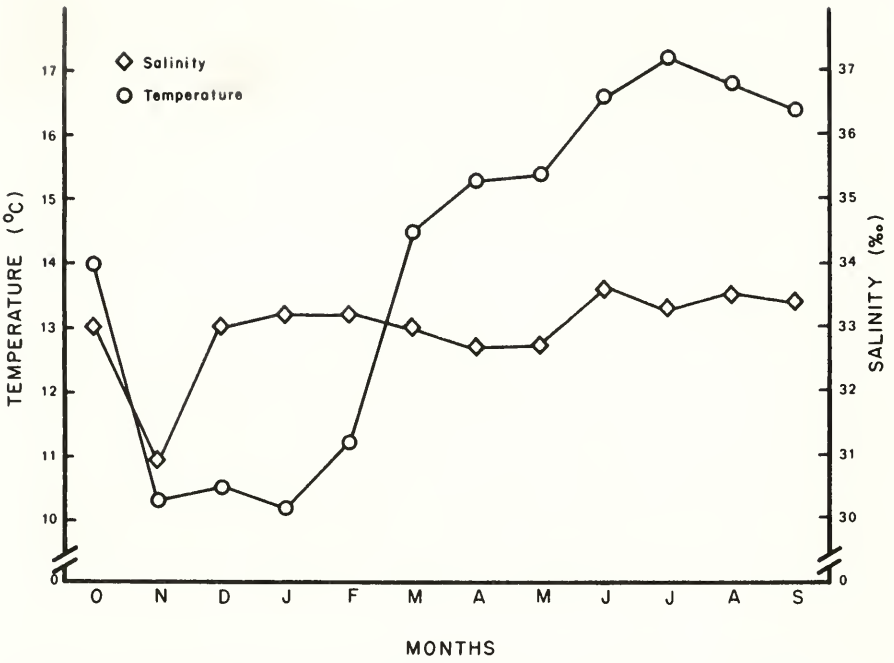

FIGURE 2. The average monthly water temperature and salinity (surface and bottom values combined) at the study site in Elkhorn Slough, 1971–72.

Leopard Shark

Four-hundred-twenty-two leopard sharks were captured. Individuals ranged in size from 40 to 140 cm TL. Leopard sharks were commonly captured in Elkhorn Slough during all seasons (Figure 3). Although gill nets did not function properly in June and July, leopard sharks were frequently caught during these months by fishermen (Talent, unpubl. data). Pronounced differences existed in the seasonal length-frequency distribution of leopard sharks more than 60 cm TL (Figure 4). Leopard sharks 60 to 100 cm TL were commonly captured during summer and fall but relatively few were captured during winter and spring. Leopard sharks 100 to 140 cm TL were captured in all seasons but were particularly abundant in winter and spring.

The smallest gravid female (i.e., containing eggs or embryos in uterine oviducts) was 104 cm TL. The number of eggs or embryos found in uterine oviducts of gravid leopard sharks ranged from 6 to 24. All gravid females examined in April contained near-term young but many of those examined in late May contained eggs with little embryonic development. Thus, leopard sharks apparently gave birth to young in Elkhorn Slough during April and May.

Bat Ray

One-hundred-fifty-two bat rays, ranging in size from 20 to 140 cm DW, were captured. Bat rays were commonly captured in Elkhorn Slough throughout spring, summer, and fall but fewer were captured in winter (Figure 3). Although

the disc width-frequency distribution of bat rays varied seasonally, bat rays less than 60 cm DW were captured more frequently than large bat rays during all seasons. However, gill nets were not efficient at capturing large bat rays. Therefore, the size distribution captured did not reflect the relative abundance of the different size classes of bat rays present in Elkhorn Slough.

The smallest gravid female was 105 cm DW. Reproductively mature females captured in June 1972 by fishermen contained from 2 to 6 fully developed young in their uterine oviducts. But mature females captured in August contained eggs with little embryonic development. Apparently, bat rays gave birth in Elkhorn Slough during July and August.

Gray Smoothhound

Sixty-nine gray smoothhounds, ranging in size from 60 to 120 cm TL, were captured in Elkhorn Slough. Gray smoothhounds were commonly captured in winter and early spring but were captured infrequently during other parts of the year (Figure 3). No seasonal changes in length-frequency distribution of gray smoothhounds were apparent.

The smallest gravid female was 87.5 cm TL. Gravid females contained from 3 to 16 developing embryos in their uterine oviducts. No gravid females containing full-term embryos were captured at the study site which suggests that gray smoothhounds did not give birth to young in the slough.

Round Stingray

Forty-eight round stingrays were captured. Individuals ranged in size from 20 to 25 cm DW and were all mature males except for one mature female. Round stingrays were frequently captured during winter but were rarely captured during other parts of the year (Figure 3).

Neither gravid female nor juvenile round stingrays were captured during the study which strongly suggests that round stingrays do not breed in Elkhorn Slough.

Shovelnose Guitarfish

Forty shovelnose guitarfish were captured in Elkhorn Slough. These ranged in size from 60 to 150 cm TL. Shovelnose guitarfish were commonly captured in gill nets during fall and early winter but were captured infrequently during other parts of the year (Figure 3). Shovelnose guitarfish, however, were also commonly captured during June and July by fishermen, months during which gill nets did not function. No seasonal changes in length-frequency distribution of shovelnose guitarfish were apparent during the period they were captured in Elkhorn Slough.

The smallest gravid female was 110 cm TL. Only eggs with little embryonic development were found in uterine oviducts of mature females captured in the slough. Thus, no evidence was found to suggest parturition took place in Elkhorn Slough.

Brown Smoothhound

Twenty brown smoothhounds were captured at the study site; individuals ranged in size from 40 to 100 cm TL. Brown smoothhounds were commonly captured in Elkhorn Slough in spring but were captured infrequently during other seasons (Figure 3). No seasonal changes in length-frequency distribution of brown smoothhounds were observed.

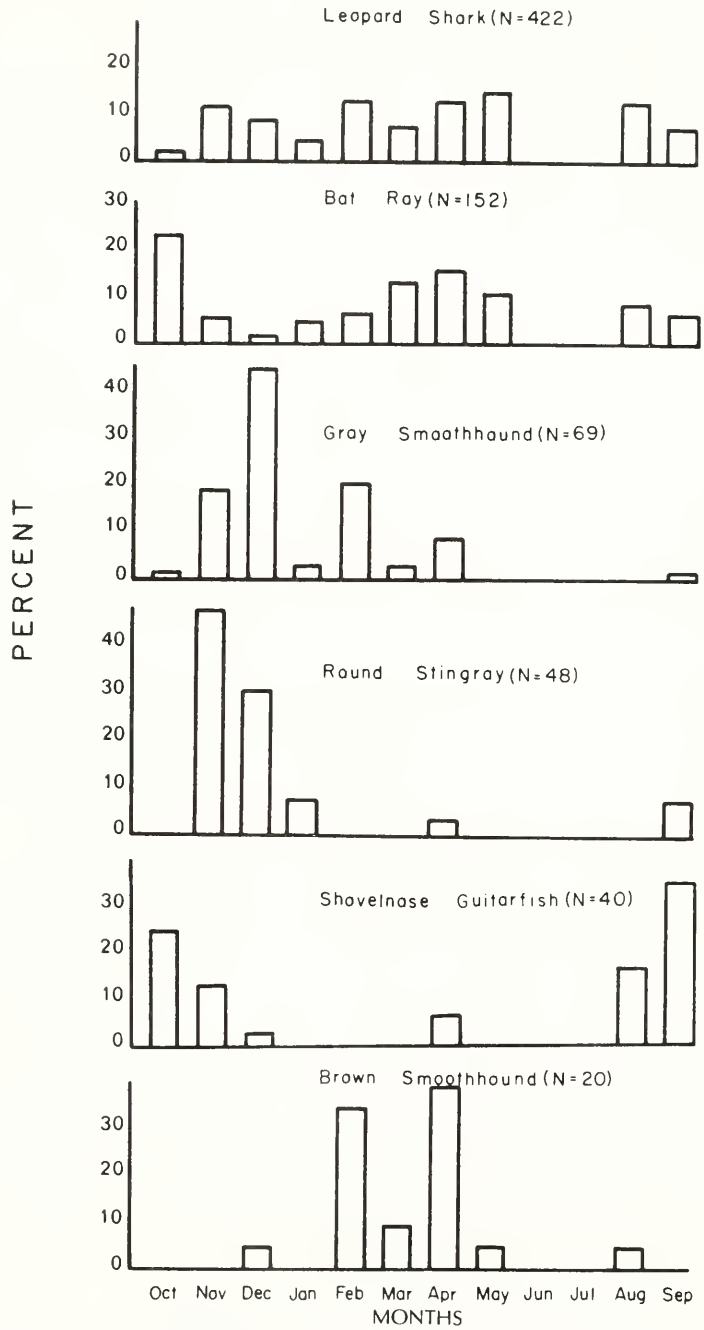

FIGURE 3. Seasonal distribution of elasmobranch fishes captured in Elkhorn Slough, 1971–72.

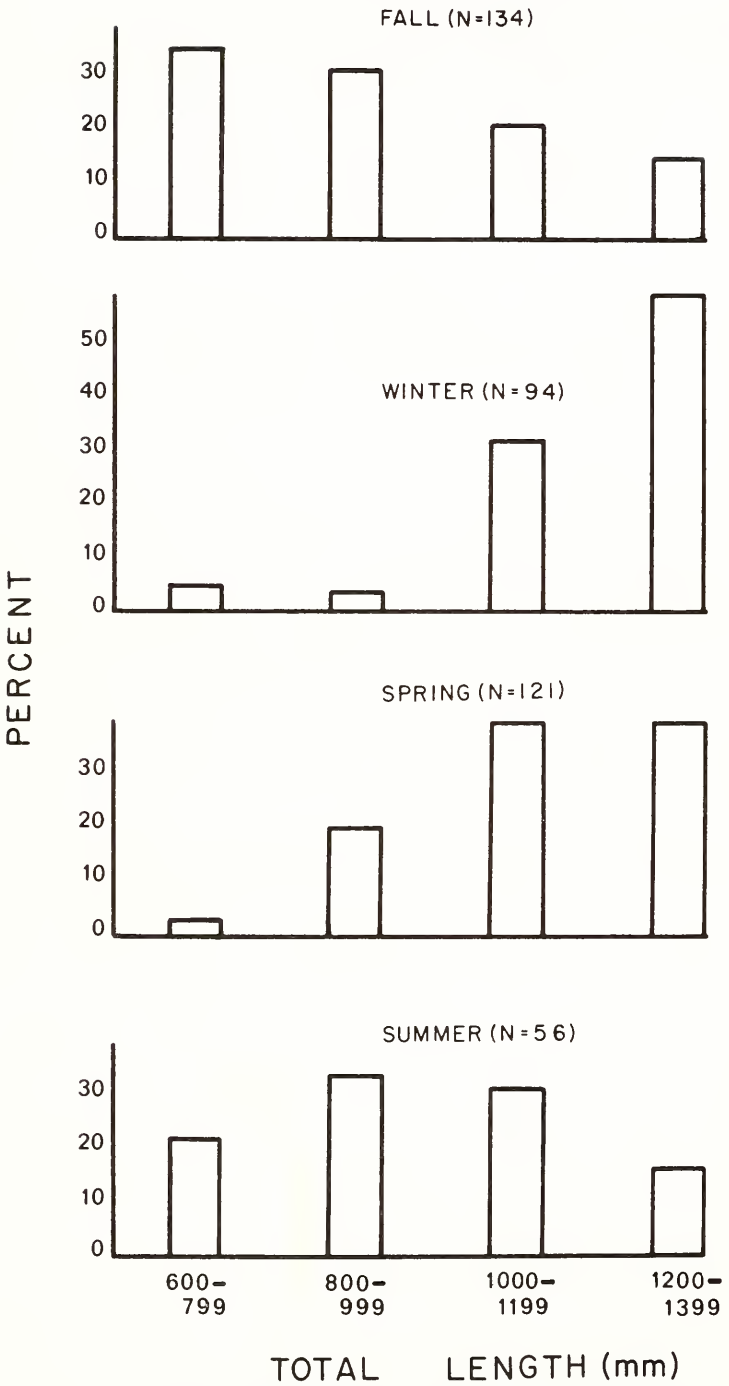

FIGURE 4. Seasonal length-frequency distribution of leopard sharks, *Triakis semifasciata*, captured in Elkhorn Slough, 1971–72.

The smallest gravid female was 67 cm TL. Gravid females contained from 1 to 8 developing embryos in their uterine oviducts. However, no females containing full-term young in their oviducts were captured which suggests that few, if any, brown smoothhounds give birth in the slough.

Thornback

Thornbacks were rare at the study site; only one was captured during the entire study. This specimen was a mature male and was captured during fall.

DISCUSSION

A minimum of seven species of elasmobranch fishes frequented the study area in Elkhorn Slough. The study area, however, was not utilized by all seven species during all seasons. Leopard sharks and bat rays were commonly captured throughout the year but gray smoothhounds, brown smoothhounds, shovelnose guitarfish, and round stingrays were only seasonally common. Thornbacks were apparently rare at the study site during all seasons.

The causes of the seasonal patterns of distribution of elasmobranchs at the study site are unknown. It is unlikely that my sampling activities biased the seasonal patterns of occurrence observed during this study because a tagging study indicated that less than 10% of any population of elasmobranch using the study area was collected (Talent, unpubl. data). In addition, salinity probably was not a major factor affecting seasonal abundance of any species of elasmobranch at the study area because salinity varied little from seawater throughout most of the year. November was the only period during which salinity was reduced by rainfall. During this period, salinity at the study area was lowered to about 31 ‰ but no reduction in the number of elasmobranchs captured was observed. However, there is a need to study the seasonal distribution of elasmobranchs in Elkhorn Slough during years with heavy rainfall to determine the effects of lower salinities.

The temperature cycle at the study area possibly affected the seasonal distribution of some elasmobranchs. Monthly averages of surface and bottom water temperature at the study area ranged from a low of 10.1°C in winter to a high of 17.2°C in summer. This cycle of temperature change occurs fairly regularly in the Monterey Bay area but may occur several weeks earlier or later during different years (Johnson 1961). Gray smoothhounds and round stingrays were most abundant when water temperature was below 11°C whereas shovelnose guitarfish were most abundant when water temperature was above 14°C. Additionally, predominantly large mature leopard sharks were captured when water temperature was below 11°C, whereas predominantly immature leopard sharks were captured when water temperature was above 14°C. There appeared to be little correlation, however, between water temperature and the seasonal distribution of bat rays and brown smoothhounds. Although water temperature may be one factor affecting the seasonal distribution of elasmobranchs, other factors such as food availability, competition, and reproductive activity probably also affect seasonal distribution.

Elkhorn Slough may be of great importance to the life histories of some populations. The rich invertebrate fauna in the slough is an important food source for elasmobranch fishes (Talent 1976, 1982). Furthermore, the slough may be a nursery area for elasmobranchs. During the study many leopard sharks and bat rays apparently gave birth in Elkhorn Slough. Although there was no

evidence that Elkhorn Slough was an important breeding area for other species of elasmobranchs, some individuals probably do breed in the slough. Specifically, a few shovelnose guitarfish may occasionally breed in the slough. The presence of very small shovelnose guitarfish in stomach contents of leopard sharks captured in Elkhorn Slough (Talent 1976) and the occasional capture of very small individuals in the slough with seines (Talent, unpubl. data) seems to support this contention.

The presence of round stingrays in Elkhorn Slough raises some interesting questions. Babel (1967) found that in southern California, adult round stingrays were non-migratory and moved only short distances over a period of years. However, my data indicated the population of round stingrays occurring in Elkhorn Slough was migratory. In addition, the occurrence of 47 males out of a total of 48 specimens collected strongly supports the contention of Herald et al. (1960) that sexual segregation occurs in Elkhorn Slough.

If the seasonal occurrence of elasmobranchs at the study site is reflective of elasmobranch occurrence in Elkhorn Slough, then gray smoothhounds, brown smoothhounds, shovelnose guitarfish and round stingrays, as well as different size classes of leopard sharks and bat rays, utilized the slough for only part of the year and, therefore, are migratory. Leopard sharks can migrate long distances between habitats; one adult female was recaptured 112 km north in San Francisco Bay one year after it was tagged in Elkhorn Slough (Talent, unpubl. data). Little, however, is known about the seasonal movement patterns of the elasmobranch species frequenting Elkhorn Slough. Research must be conducted on marked elasmobranchs along the Pacific Coast to determine age specific migratory patterns before the seasonal patterns of occurrence of these fishes in Elkhorn Slough and other embayments can be fully evaluated.

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EFFECTS ON WILDLIFE OF ETHYL AND METHYL PARATHION APPLIED TO CALIFORNIA RICE FIELDS [1]

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Selected rice fields on the Sacramento National Wildlife Refuge Complex were aerially sprayed one time during May or June 1982 with either ethyl (0.11 kg AI/ha) or methyl (0.84 kg AI/ha) parathion for control of tadpole shrimp, *Triops longicaudatus*. No sick or dead vertebrate wildlife were found in or adjacent to the treated rice fields after spraying. Specimens of the following birds and mammals were assayed for brain cholinesterase (ChE) activity to determine exposure to either form of parathion: house mouse, *Mus musculus;* black-tailed jackrabbit, *Lepus californicus;* mallard, *Anas platyrhynchos;* ring-necked pheasant, *Phasianus colchicus;* American coot, *Fulica americana;* and red-winged blackbird, *Agelaius phoeniceus*. Both mice and pheasants from methyl parathion-treated fields had overall mean ChE activities that were significantly ($P < .05$) inhibited compared with controls, and 7, 40, 54, and 57% of individual blackbirds, pheasants, mice, and coots, respectively, had inhibited brain ChE activities (i.e., less than −2 SD of control mean). Although no overall species effect was detected for ethyl parathion treatment, pheasants (43%), coots (33%), and mice (37%) had significantly inhibited brain ChE activities. Neither of the parathion treatments appeared acutely hazardous to wildlife in or adjacent to rice fields, but sufficient information on potential hazards was obtained to warrant caution in use of these chemicals, especially methyl parathion, in rice fields.

INTRODUCTION

Ethyl parathion [phosphorothioic acid *O,O*-diethyl *O*-(4-nitrophenyl) ester] and methyl parathion [phosphorothioic acid *O,O*-dimethyl *O*-(4-nitrophenyl) ester] are two organophosphorus insecticides that receive diverse use on North American croplands and are the principal insecticides used on California rice (Calif. Dept. Food Agric. 1982). Both forms of parathion are highly toxic to, wildlife (Hill et al. 1975; Hudson, Tucker, and Heagele 1984; Schafer et al. 1983), however only ethyl parathion has been repeatedly implicated in field mortalities of wildlife (Mills 1973; Stone 1979; White et al. 1979, 1982; Grue et al. 1983; Stone, Overmann, and Okoniewski 1984) even though methyl parathion is one of the most widely used insecticides in the United States. Because of the agricul-

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tural importance of these closely related insecticides and the disparity of their effects on wildlife, we conducted a study of the two chemicals to determine whether either was detrimental to wildlife when applied to rice by standard aerial methods. The Sacramento National Wildlife Refuge Complex (SNWRC), California, including four refuges and over 8,100 ha of marsh and cropland, was selected for the study because special land-use permits are issued for rice farming and about two-thirds of the crop (about 800 ha) may be treated with pesticides and harvested; the remainder of the rice crop cannot be treated or harvested. Brain cholinesterase activity in random-captured wildlife was our primary means of evaluating exposure (Bunyan, Jennings, and Taylor 1968; Zinkel et al. 1980; DeWeese et al. 1983).

METHODS

Selected rice fields on SNWRC were sprayed once during May or June 1982 with either ethyl or methyl parathion for control of tadpole shrimp. Ethyl parathion was applied at 0.11 kg AI (active ingredient)/ha (= 0.1 lb/acre) on 21 May by helicopter from 3 m altitude or less at an air speed of 80 kph on 260 ha of rice on the Sacramento National Wildlife Refuge (NWR). It was also applied on 8 June by fixed-wing aircraft from 2 m altitude or less at an air speed of 190 kph on 72 ha of rice on the Sutter NWR. Methyl parathion was applied at 0.84 kg AI/ha (= 0.75 lb/acre) by helicopter from 3 m altitude or less at an air speed of 80 kph on 32 ha (20 May) and 70 ha (25 May) rice fields on the Colusa NWR.

The effects of each treatment on wildlife were evaluated by routine observations of animal activities on and adjacent to parathion-treated rice fields, and by opportunistic sampling of animals within a 20-m bound of the fields on the second and third days postspray. All animals except house mice were shot, decapitated, and their heads frozen on dry ice preparatory for ChE assay. House mice were live-trapped but otherwise handled the same as other species. Controls were collected and stored as above from untreated sites on the SNWRC before any spraying was performed. Specimens studied included both sexes of house mouse, black-tailed jackrabbit, and American coot, and males only of ring-necked pheasant, mallard, and red-winged blackbird. Whole brain ChE activity (based on longitudinally bisected half brains) were assayed at 25°C by the method of Ellman et al. (1961) as described by Hill and Fleming (1982). Brain cholinesterase (ChE; predominately acetylcholinesterase, EC 3.1.1.7) activity of each animal was then compared with the prespray norm for the species as described by Hill and Fleming (1982). Individuals from like treatments were also pooled and compared by one (single sex) or two-way (multiple sex) analysis of variance ($\alpha = .05$). The Bonferroni multiple comparison method was used to separate means (Miller 1981).

RESULTS

Although intensive searches were not conducted, general observations were continued on and adjacent to the treated rice fields for 10 days postspraying and no sick or dead birds or mammals were found.

Ring-necked pheasants and house mice collected near rice fields after application of 0.84 kg AI/ha methyl parathion had significantly ($P < .05$) lower brain ChE activity than either controls or those from fields treated with 0.11 kg AI/ha ethyl parathion (Table 1). Maximum brain ChE inhibition from methyl parathion was 39% for both pheasants and mice. Even though mean brain ChE activities

in red-winged blackbirds and American coots were not significantly inhibited by the methyl parathion treatments, 7 and 57% of the individuals sampled had brain ChE activities below the norm (i.e., −2 SD of control mean; Hill and Fleming 1982) for the species. Mean brain ChE activity was not significantly reduced for any of the species collected near ethyl parathion-treated rice fields. However, individual brain ChE activities were below the norm for individual pheasants, coots, and mice, but not mallards, blackbirds, or rabbits. Maximum ethyl parathion-induced brain ChE inhibition for pheasants, coots, and mice was 18, 15, and 52%, respectively. No between-sex differences were detected for coots, house mice, or jackrabbits [two-way analysis of variance ($\alpha = .05$)].

TABLE 1. Brain ChE Activity (μmol/min/g, wet weight) in Birds and Mammals Collected Near Rice Fields on the Sacramento National Wildlife Refuge Complex, 1982.

Species	*Treatment*	*N*	*Mean*	*SD*	*Extremes*	*Individual respondents*[1]
Ring-necked pheasant	Control	10	13.5 A[2]	0.82	12.7 and 15.7	(11.9)
	Ethyl parathion	7	12.2 A	0.88	11.1 and 13.4	3
	Methyl parathion	5	11.5 B	2.04	8.2 and 13.4	2
Mallard	Control	5	8.9	1.28	7.5 and 11.0	(6.4)
	Ethyl parathion	6	8.6	0.67	7.8 and 9.4	0
Red-winged blackbird	Control	10	19.1	1.84	16.4 and 22.0	(15.4)
	Ethyl parathion	9	20.0	1.20	17.6 and 21.1	0
	Methyl parathion	14	18.5	1.45	14.3 and 20.0	1
American coot	Control	2	18.8	1.06	18.1 and 19.6	(16.7)
	Ethyl parathion	3	17.0	0.91	16.0 and 17.7	1
	Methyl parathion	7	15.6	3.60	10.3 and 20.1	4
House mouse	Control	19	5.4 A[3]	0.40	4.7 and 6.1	(4.6)
	Ethyl parathion	19	5.3 A	0.87	2.6 and 6.5	2
	Methyl parathion	13	4.7 B	0.51	3.3 and 5.2	5
Black-tailed jackrabbit	Control	5	6.2	0.78	5.2 and 7.3	(4.7)
	Ethyl parathion	4	6.8	1.17	5.9 and 8.5	0

[1] Individual respondents = no. of parathion-exposed animals below parenthesized diagnostic threshold, (i.e., < −2 SD of control mean).

[2] Means not sharing the same letter are significantly different from one another (ANOVA, $\alpha = .05$).

[3] Means not sharing the same letters are significantly different from one another [(two-way ANOVA, sex (2), treatment (3), $\alpha = .05$, Bonferroni multiple comparison method)]. There was no significant between-sex difference.

DISCUSSION

Our findings of no mortality and mean inhibition of brain ChE activity of 15% for ring-necked pheasants following an application of 0.84 kg AI/ha methyl parathion are consistent with earlier studies. Methyl parathion and toxaphene (chlorinated camphene), each applied at 1.1 kg AI/ha to cotton, caused no deaths but produced an average brain ChE inhibition of 23% in bobwhite quail, *Colinus virginianus* (Smithson and Sanders 1978). No bobwhite or pheasant mortality was associated with a methyl parathion application of 0.56 kg AI/ha to alfalfa (Edwards and Graber 1968).

Although the mentioned applications of methyl parathion at 0.56 to 1.1 kg A I/ha were not found lethal under conditions of the various studies, there is evidence that the very young of precocial species may be affected by such

treatments. Three-day-old pheasants displayed nervous disorders when exposed to a methyl parathion application of 0.3 kg AI/ha, and 5-day-old chicks died at 0.6 kg AI/ha but neither treatment affected 10-day-old pheasants (Christensen 1969). Gallinaceous birds less than 2 wk old are shown less tolerant of both field application (Messick et al. 1974) and controlled dietary exposure (Ludke, Hill, and Dieter 1975; Hill and Camardese 1981) of organophosphorus pesticides than even 1-mo-old chicks. This age disparity of tolerance of organophosphates did not occur in acute tests with mallards from 36 h to 6 months of age (Hudson, Tucker, and Haegele 1972).

The ethyl parathion application of 0.11 kg AI/ha in our study was well below that reported to affect wildlife. Pinioned mallards on ponds sprayed with 0.45 kg AI/ha ethyl parathion six times at biweekly intervals (Keith and Mulla 1966) or once at 1.12 kg AI/ha (Mulla, Keith, and Gunther 1966) showed no mortality. When fields were sprayed with 0.9 kg AI/ha ethyl parathion, adult pheasants exhibited neither mortality nor inhibition of brain ChE activity (Messick et al. 1974). Wolfe, Baxter, and Munson (1971) found no behavioral changes or mortality of 9-wk-old pheasants sprayed with 0.56 kg AI/ha ethyl parathion on grain sorghum; average brain ChE activity was depressed by about 20%.

We conclude that ethyl parathion applied at 0.11 kg AI/ha to rice poses no lethal threat to wildlife, and although we observed no mortality, methyl parathion at $\geq$ 0.84 kg AI/ha may pose some hazard. This latter conclusion is based on mentioned published evidence of early chick mortality (Christensen 1969), and our demonstration of significant inhibition of brain ChE activity associated with methyl parathion exposure in at least one species each of bird and mammal.

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POPULATION BIOLOGY OF BLUEGILLS, *LEPOMIS MACROCHIRUS*, IN LOTIC HABITATS ON THE IRRIGATED SAN JOAQUIN VALLEY FLOOR[1]

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Rapid expansion of irrigated agriculture in the western United States has prompted concerns for aquatic resources. Although the impacts of irrigation activities on quality and quantity of river water are well documented (e.g., high turbidity from soil erosion, eutrophication from nutrient runoff, pesticide contamination, reduced discharge), their effects on fish populations are still poorly understood. We studied the food, growth, and relative weight (a measure of body condition) of bluegills, *Lepomis macrochirus,* in relation to environmental factors in reaches of the San Joaquin and Merced rivers that have been affected to varying degrees by irrigation return flows. Fry of bluegills ate mostly cladocerans and copepods; fingerlings and larger fish ate immature aquatic insects, terrestrial insects, amphipods, and mollusks. Bluegill stomachs were fuller and contained a higher diversity of forage taxa in habitats with low turbidity and conductivity, weak buffering capacity, and low nutrient levels; bluegills also ate a more diverse diet where the potential forage supply (benthic macroinvertebrates) was most diverse. Bluegills attained mean total lengths of about 42 mm at age I, 86 mm at age II, 116 mm at age III, 153 mm at age IV, and 166 mm at age V. Mean relative weight ranged from 96–111. Growth rate and relative weight were not significantly correlated with environmental or dietary variables. On the basis of our study, we concluded that environmental degradation from irrigation activities affected the diet of bluegills primarily by modifying the food supply, but growth rate and body condition were not affected.

INTRODUCTION

Irrigated agriculture increased from 15 million ha in 1964 to nearly 17 million ha by 1974 in the United States (U.S. Bureau of the Census 1978). Over 88% of the new acreage was in the 17 westernmost states and Louisiana. In California, more than 90% of the 3.3 million ha of cropland harvested in 1974 was irrigated.

The rapid growth of irrigation has led to concerns that irrigation-related activities may be detrimental to aquatic biota. In the San Joaquin Valley of California, where crops have been grown for over a century, irrigated agriculture is currently the most prevalent land use (California Department of Water Resources 1960, 1969). During the irrigation season (usually March to October) return flows from irrigated fields constitute most of the discharge in low-elevation rivers (California Department of Water Resources 1960).

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Numerous investigators (e.g., Sylvester and Seabloom 1963, Hotes and Pearson 1977, Miller et al. 1978) have reported that altered temperature and flow regimes, and increased concentrations of dissolved salts, pesticides, sediments, agricultural fertilizers, and animal wastes are among the environmental changes typical of rivers that drain irrigated watersheds. In the San Joaquin Valley, physical and chemical characteristics of rivers are influenced considerably by irrigation activities (Sorenson and Hoffman 1981, Sorenson 1982, Saiki 1984). Although recent attempts have been made to assess the effects of general agricultural land use on aquatic life (e.g., Mitchell 1975; Welch, Symons, and Narver 1977; Dance and Hynes 1980; Luey and Adelman 1980; Marsh and Waters 1980), few studies have specifically addressed the effects of irrigated agriculture on fish populations.

This study was part of a broader ecological investigation designed to profile environmental conditions in low elevation rivers on the San Joaquin Valley floor. Our major objectives were to (i) describe the food, growth, and body condition of different populations of resident bluegills, *Lepomis macrochirus,* from different locations on the rivers, and (ii) determine if any differences in these biological characteristics are associated with environmental changes from irrigation. The bluegill was studied because it is an important warmwater game fish that is common throughout most of the study area (Saiki 1984). The ecology and general life history of bluegills that inhabit lakes and reservoirs have been well studied in California and elsewhere (see reviews and bibliographies by Emig 1966; Carlander 1977; Hartmann, Hartmann, and von Geldern 1978; and others); however, almost no information is available for populations from lotic habitats on the floor of the San Joaquin Valley.

STUDY AREA

The San Joaquin Valley floor occupies about 3.4 million ha bounded by the Sierra Nevada on the east, the Coast Range on the west, the Tehachapi Mountains on the south, and the Sacramento-San Joaquin Delta on the north. The Valley floor is one of the most important agricultural areas of California. Major crops are cotton, grapes, tomatoes, hay, sugar beets, and vegetables. An arid climate (13–36 cm of rainfall/yr characterized by hot summers and cool winters necessitates irrigation on about 1.8 million ha of croplands.

Nine reaches (includes the mainstream and small backwaters flushed by the mainstream) were sampled on the San Joaquin River and two of its tributaries, the Merced River and Salt Slough (Figure 1). The San Joaquin and Merced rivers originate in the Sierra Nevada, and their initial water supplies result mainly from snowmelt and rainfall. Salt Slough originates on the Valley floor and derives most of its discharge from groundwater seepage and irrigation return flows.

The physicochemical characteristics of the study reaches showed longitudinal (upstream to downstream) trends indicative of progressively increasing environmental degradation (Saiki 1984). The most conspicuous of these trends were in turbidity, total alkalinity, and conductivity (Table 1). Concentrations of macronutrients also increased upstream to downstream—especially NO_3+NO_2–N and ortho-PO_4. Water quality improved somewhat in the San Joaquin River below SJR-4 (see Figure 1 for names and locations of sampling reaches) due to inflows of higher quality water from tributary streams. Dissolved oxygen concentrations typically exceeded 4 mg/ l (50% saturation) at all reaches, and were never low enough to constitute a hazard to fishes. The pH was typically 7.0 to 8.9.

Benthic macroinvertebrate communities were dominated by the Asiatic clam, *Corbicula fluminea;* chironomid larvae, and oligochaetes (Sorenson and Hoffman 1981; M. K. Saiki, unpub. data). During our study, benthic standing crops were usually higher and communities more diverse in the upstream than in the downstream reaches of both the San Joaquin and Merced rivers (Table 2).

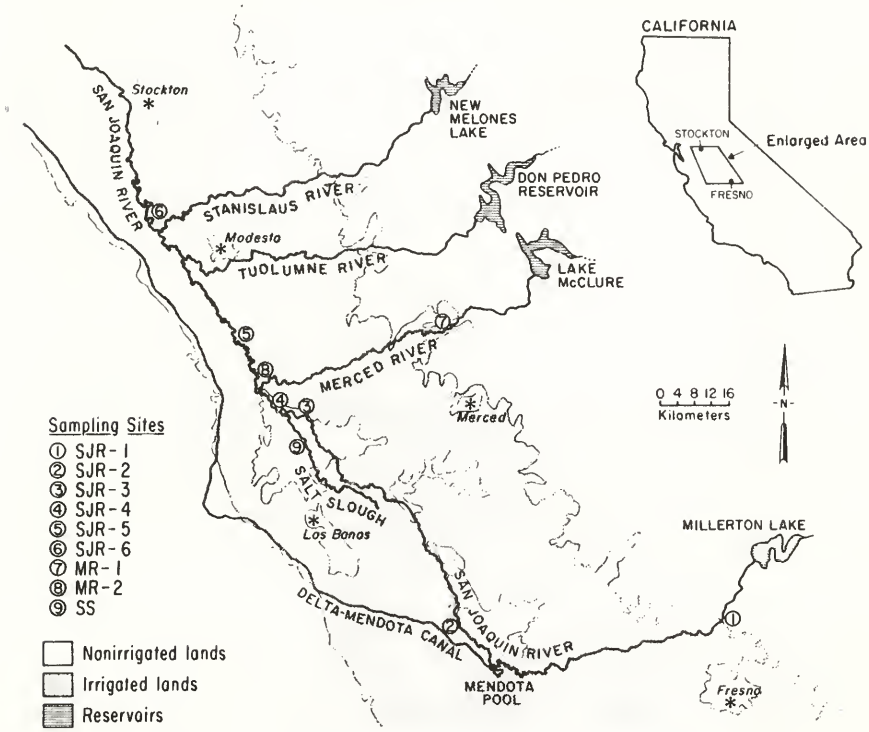

FIGURE 1. Locations of sampling reaches and irrigated croplands in the study area. Names of reaches are as follows: SJR-1, San Joaquin River near Fort Washington; SJR-2, San Joaquin River at Firebaugh; SJR-3, San Joaquin River at Lander Avenue; SJR-4, San Joaquin River at Fremont Ford State Recreational Area; SJR-5, San Joaquin River near Crows Landing; SJR-6, San Joaquin River at South County Park; Salt Slough, Salt Slough below Lander Avenue; MR-1, Merced River below Highway 59; and MR-2, Merced River at George J. Hatfield State Recreational Area.

The composition of fish communities and relative abundance of individual species in the study reaches differed upstream to downstream (Saiki 1984). Species that occurred primarily at upstream reaches included sculpins, *Cottus* spp.; green sunfish, *Lepomis cyanellus;* redear sunfish, *L. microlophus;* Sacramento squawfish, *Ptychocheilus grandis;* hardhead, *Mylopharodon conocephalus;* and threespine stickleback, *Gasterosteus aculeatus.* Downstream reaches were dominated by inland silverside, *Menidia beryllina;* white crappie, *Pomoxis annularis;* threadfin shad, *Dorosoma petenense;* fathead minnow, *Pimephales promelas;* splittail, *Pogonichthys macrolepidotus;* Sacramento blackfish, *Orthodon microlepidotus;* tule perch, *Hysterocarpus traski;* and striped bass, *Morone saxatilis.* Besides bluegills, largemouth bass, *Micropterus salmoides;* black crappie, *Pomoxis nigromaculatus;* and mosquitofish, *Gambusia affinis* were commonly found both upstream and downstream.

TABLE 1. Environmental Variables Measured at Selected Reaches on the San Joaquin and Merced Rivers, and Salt Slough. Values are Means Calculated from Data Collected in July 1980–November 1981 and Adjusted for a 1-year Interval.[a]

	Reach[b]								
Type of variable, and unit	*SJR-1*	*SJR-2*	*SJR-3*[c]	*SJR-4*	*SJR-5*	*SJR-6*	*Salt Slough*	*MR-1*	*MR-2*
Physical									
Water temperature, °C	15.6	18.2	19.0	18.0	17.6	16.8	18.5	14.3	18.0
Conductivity, µmhos/cm @ 25°C	57	637	1,107	1,721	1,209	816	1,947	49	199
Turbidity, NTU's	3.2	18.6	21.3	25.0	20.1	17.5	27.0	1.7	5.7
Discharge, m^3/s	4.5	7.1	2.5	8.3	26.0	57.4	5.2	6.5	9.8
Sediment fineness[d]	0.036	0.009	0.006	0.007	0.009	0.006	0.008	0.066	0.006
Chemical									
Dissolved oxygen, mg/l	10.4	10.3	11.9	9.5	8.9	8.0	8.1	9.8	9.3
pH	7.8	8.0	8.3	8.1	7.8	7.9	7.8	7.9	7.9
Total alkalinity, mg/l $CaCO_3$	20	89	176	167	132	116	173	20	57
NH_3-N, mg/l	0.05	0.04	ND	0.32	0.07	0.14	0.15	0.01	0.11
NO_3+NO_2-N, mg/l	0.14	0.80	ND	1.85	1.51	1.62	1.92	0.03	1.45
Total N, mg/l	0.30	1.00	ND	1.90	1.54	1.76	1.94	0.14	1.53
Ortho-PO_4, mg/l	0.01	0.12	ND	0.21	0.02	0.18	0.16	0.01	0.07
Total P, mg/l	0.04	0.19	ND	0.24	0.19	0.23	0.22	0.03	0.12

[a] Data from Saiki (1984).
[b] See Figure 1 for names and locations of reaches.
[c] ND = no data.
[d] Schoklitsch's sediment factor *s* may assume any arbitrary positive value, with higher vaues indicating coarser sediment material (Bogardi 1974).

TABLE 2. Mean Annual Standing Crops and Shannon-Weaver Diversities ($\bar{d}$) of Benthic Invertebrates from Selected Reaches of the San Joaquin and Merced Rivers, and Salt Slough, July 1980–October 1981.

Reach[+]	*Standing crop* (g/m^2 *wet weight*)	$\bar{d}$ *
SJR-1	3.48	2.35
SJR-2	0.74	0.58
SJR-3	0.91	0.98
SJR-4	0.47	1.59
SJR-5	0.28	2.11
SJR-6	1.07	1.85
Salt Slough	0.73	0.81
MR-1	2.46	2.31
MR-2	1.07	2.39

[+] See Figure 1 for names and locations of reaches.
* Calculated from unpublished data of M. K. Saiki.

METHODS AND MATERIALS

Bluegills were collected monthly from July 1980 through October 1981 at SJR-1 and SJR-4. At all other reaches, we made collections every three months during the same period, except that sampling was terminated after October 1980 at SJR-3 and started in January 1981 at SJR-6. Bluegills were captured with two seines—one 5.5 m long by 2.4 m deep with 9.5-mm square mesh, and one 30.5 m long by 1.8 m deep with 12.7-mm square mesh. Fish were also collected by backpack electrofishing at SJR-1, MR-1, and MR-2; other sites were too turbid and the conductivities too high for effective electrofishing.

Immediately after capture, bluegills were measured (total length), and scales were removed for age and growth analysis. The fish were then preserved in 10% formalin.

After returning from the field, we weighed and sexed bluegills by dissection. Stomach contents were removed from the anterior end of the esophagus to the pyloric sphincter, and food items were identified with the help of taxonomic keys (Pennak 1953, Usinger 1971, Merrit and Cummins 1978).

The fullness of the digestive tracts of bluegills (C_r, an index of the amount of food eaten) was estimated from the formula

$$C_r = (A \times 100\%)/(W - A)$$

where A is the weight of all food items in a fish's stomach and W is the weight of the fish. This formula is a modification of I_r (= L'indice de repletion = fullness index) that was first defined by Hureau (1969, cited by Berg 1979).

Diversity ($\bar{d}$) of food was computed from the Shannon-Weaver formula

$$\bar{d} = 3.321928/W \ (W \log_{10} W - \Sigma W_i \log_{10} W_i)$$

where W is the total biomass of individuals in the sample and W_i is the biomass of individuals in taxon i (Weber 1973). Wilhm (1968) showed that the use of biomass units does not influence the estimate of $\bar{d}$.

Food overlap (C_λ) was calculated from the formula

$$C_\lambda = \left(2 \sum_{i=1}^{s} X_i Y_i\right) \Big/ \left(\sum_{i=1}^{s} X_i + \sum_{i=1}^{s} Y_i\right)$$

where s is the total number of food taxa, X_i is the proportion of the total diet from site X composed of taxon i, and Y_i is the proportion of the total diet from site Y composed of taxon i (Zaret and Rand 1971). The value of C_λ can vary

from 0 (when the samples contain no taxa in common) to 1 (when the samples are identical). The determination of a "significant" C is arbitrary, and depends on the experience and judgment of the investigator. Zaret and Rand (1971) assumed that $C \geq 0.60$ was significant overlap in their study of tropical stream fish diets; we interpreted $C_\lambda \geq 0.70$ as significant overlap.

Individual fish were aged by counting annuli on scales. The procedure described by Brown, Miller, and von Geldern (1977) was used to identify new annuli. The body-scale relation was computed, and growth was back-calculated according to the Fraser-Lee method cited by Bagenal and Tesch (1978).

Relative weight (W_r) of individual bluegills, a measure of body condition, was computed from the formula

$$W_r = W/W_s \times 100$$

where W is the actual weight of the fish and W_s is a standard weight (Wege and Anderson 1978, Anderson 1980). According to Wege and Anderson (1978), W_r is easier to interpret than most other condition indices (e.g., C, K, or K_n) because its values can be compared directly between fish of different lengths and from different populations. Furthermore, the calculation of W_r is simple and values do not change with different units of measure.

RESULTS

Food

Of 1,675 bluegill stomachs that we examined, 95% (1,600) contained food. The arcsine-transformed percentage of stomachs with food (based on four size classes of bluegills: ≤ 25, 26-50, 51-100, and >100 mm) was not significantly correlated with total length of the fish ($r = 0.26$, $df = 33$, $P > .05$). Comparisons of stomachs with food vs. empty stomachs (based on the combined size classes of bluegills from all reaches) indicated significant seasonal differences ($\chi^2 = 24.05$, $df = 3$, $P < .01$); stomachs with food occurred most frequently in spring (April–June, 99%), followed by summer (July–September, 97%), fall (October–December, 93%), and winter (January–March, 92%). Among reaches, the proportions of stomachs with food vs. empty stomachs differed significantly ($\chi^2 = 21.95$, $df = 8$, $P < .01$), but longitudinal trends (upstream to downstream) were not apparent.

Stomach Fullness and Diet Diversity

The fullness index (C_r) was inversely correlated with fish size class ($r = -0.25$, $df = 105$, $P < .01$), indicating that the stomachs of smaller fish typically contained more food relative to body weight than did those of larger fish. Therefore, comparisons of C_r over seasons and reaches required adjustment of the data to eliminate the influence of fish size. Consequently, we excluded all fish < 25 mm long because this size class was usually available only in spring and summer, and also deleted data from SJR-3 and Salt Slough where we failed to collect all size classes of fish >25 mm year round. One-way Analysis of Variance (ANOVA) performed on the arcsine-transformed proportions demonstrated that seasonal differences for C_r were significant ($F_{3,80} = 3.90$, $P < .05$). Further testing [Fischer's Protected Least Significant Difference (LSD)] showed that the winter mean (0.33%) was significantly ($P < .05$) lower than the means for the other seasons (spring, 0.52%; summer, 0.55%; fall, 0.53%), which did

not differ significantly among themselves. The mean annual C, values for the eight reaches (range = 0.35–0.56%) did not differ significantly ($F_{6,77} = 0.88$, $P > 0.05$).

Diet diversity was positively correlated with total length ($r = 0.66$, $df = 32$, $P < .01$), indicating that the variety of organisms eaten was generally wider among large than among small fish. Comparisons of diet diversity among reaches required deletion of data for fish < 25mm long because bluegills of this length were not examined from SJR-5 and Salt Slough. One-way ANOVA demonstrated that diet diversity differed significantly among reaches ($F_{8,18} = 5.75$, $P < .01$), and that, although there were some exceptions, diet diversity was generally higher in upstream than in downstream reaches (Table 3).

TABLE 3. Mean Annual Diversity of Food of Bluegills from Selected Reaches of the San Joaquin and Merced Rivers, and Salt Slough.

Reach *	*Shannon-Weaver diversity, $\bar{d}$* +
SJR-1	$3.425_{a, c, f}$
SJR-2	$1.862_{b, d, e}$
SJR-3	$1.731_{b, d, e}$
SJR-4	$2.736_{a, c, d, e, f}$
SJR-5	$2.453_{b, c, d, e, f}$
SJR-6	$2.016_{b, c, d, e}$
Salt Slough	$1.896_{b, d, e}$
MR-1	$2.991_{a, c, d, f}$
MR-2	$3.281_{a, c, f}$

* See Figure 1 for names and locations of reaches.
+ Values containing the same subscript are not significantly different ($P > .05$, LSD).

General Description of Food

The most obvious trend in food was related to fish size (Figure 2). In general, zooplankton (primarily cladocerans and copepods) constituted most of the food eaten by bluegills ≤ 25 mm long. The dietary importance of zooplankton decreased with fish size; larger bluegills ate more chironomid and trichopteran larvae, ephemeropteran nymphs, winged insects, detritus (unidentifiable organic materials), and miscellaneous materials (mostly unidentified larval aquatic insects and plants). Chironomid larvae, detritus, and miscellaneous materials were the primary foods of bluegills larger than 100 mm.

Although diets changed seasonally, chironomid larvae, zooplankton, detritus, and miscellaneous materials were always among the most frequently eaten foods (Figure 3). Ephemeropteran nymphs also were important in winter, winged insects in summer and fall, and amphipods in fall.

Chironomid larvae, zooplankton, and miscellaneous materials were major foods of fish in all reaches (Figure 4). Detritus was also an important food item everywhere except in SJR-6. Fish from upstream reaches (SJR-1, MR-1) fed more heavily on trichopteran larvae and ephemeropteran nymphs than did those from most downstream reaches; however, trichopteran larvae also were important in MR-2. Amphipods were most important as forage in SJR-4, SJR-5, and Salt Slough, whereas winged insects were important only in SJR-3 and SJR-5.

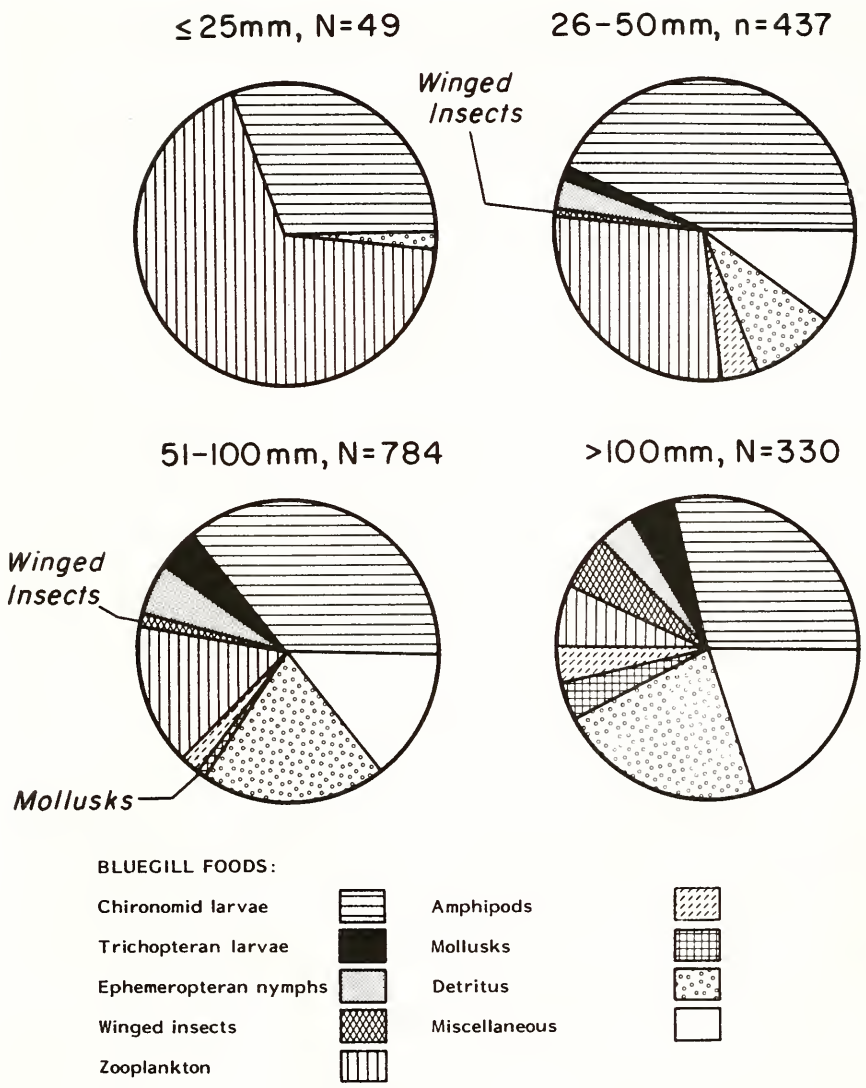

FIGURE 2. Food of various size classes of bluegills, based on unweighted annual mean damp-dry biomass from eight reaches on the San Joaquin and Merced rivers, and Salt Slough.

Food Overlap Among Reaches

Indices of food overlap between pairs of reaches were calculated only for fish longer than 25 mm. If one arbitrarily assumes that $C_\lambda > 0.70$ represents significant overlap, there were 20 overlaps between reaches (Table 4).

Food overlap occurred between the two upstream reaches (SJR-1, MR-1), with one reach (SJR-1) also overlapping a downstream reach (MR-2). Except for MR-2, all downstream reaches showed significant overlap; MR-2 overlapped only SJR-3, SJR-4, and SJR-5. These results demonstrate that, for the most part, the diets of bluegills differed between upstream and downstream reaches. However, diets in MR-2 consisted of foods characteristic of both upstream and downstream reaches.

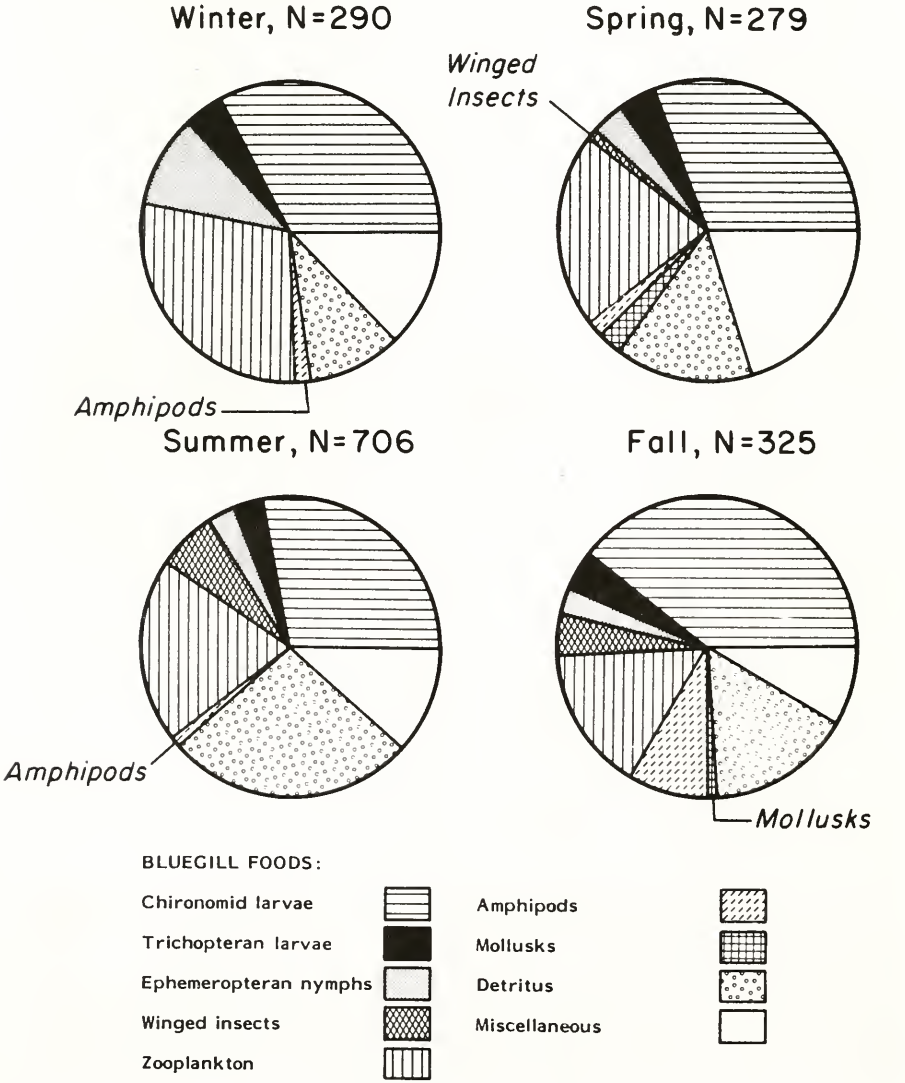

FIGURE 3. Seasonal food habits of bluegills, based on unweighted mean damp-dry biomass of four total length classes (≤ 25, 26-50, 51-100, and > 100 mm) of fish from eight reaches on the San Joaquin and Merced rivers, and Salt Slough.

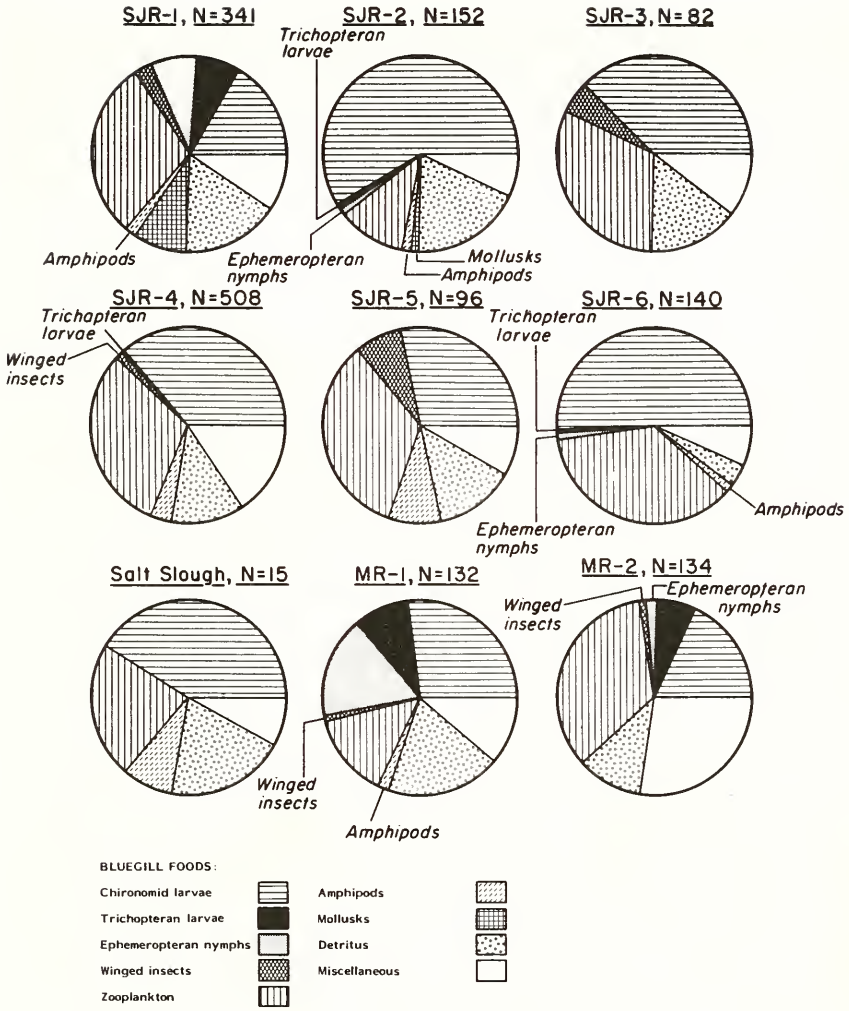

FIGURE 4. Annual food of bluegills from eight reaches on the San Joaquin and Merced rivers, and Salt Slough. Based on unweighted means (damp-dry biomass) of four total length classes (≤ 25, 26-50, 51-100, and >100 mm) of fish.

Food in Relation to Environmental Characteristics

Correlation analysis revealed that stomachs were fuller and contained a higher diversity of forage taxa in environments characterized by clear water, weak buffering capacity, and low levels of total P (Table 5). Bluegill stomachs were also fuller in areas with low conductivity and NH_3-N concentrations. When the fullness and diet diversity indices were compared with the standing crop and diversity of benthic macroinvertebrates, only the two diversity indices were significantly correlated ($r = 0.85$, $df = 7$, $P < .01$).

TABLE 4. Annual Food Overlap ($C\lambda$) among Bluegill > 25 mm TL for Pairs of Reaches on the San Joaquin and Merced Rivers, and Salt Slough.

Reach *	*SJR-1*	*SJR-2*	*SJR-3*	*SJR-4*	*SJR-5*	*SJR-6*	*Salt Slough*	*MR-1*	*MR-2*
SJR-1	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
SJR-2		1.00	0.97	0.93	0.71	0.93	0.89	0.28	0.67
SJR-3			1.00	0.97	0.77	0.92	0.93	0.32	0.73
SJR-4				1.00	0.84	0.92	0.96	0.32	0.76
SJR-5					1.00	0.77	0.84	0.52	0.82
SJR-6						1.00	0.84	0.21	0.67
Salt Slough							1.00	0.36	0.68
MR-1								1.00	0.59
MR-2									1.00

* See Figure 1 for names and locations of reaches.

TABLE 5. Product-moment Correlation Coefficients Describing Relations between Environmental Variables (Annual Means for Each Reach) and the Mean Annual Indices of Stomach Fullness (C_r) and Diet Diversity ($\bar{d}$) for Each Reach.*, +

Environmental variable	C_r	$\bar{d}$
Physical		
Water temperature	—0.44	—0.60
Conductivity	—0.77*	—0.60
Turbidity	—0.20	—0.22
Sediment fineness	0.32	0.52
Chemical		
Dissolved oxygen	0.12	0.01
pH	—0.57	—0.40
Total alkalinity	—0.82**	—0.72*
NH_3-N	—0.82**	—0.12
NO^3+NO^2-N	—0.42	—0.49
Total N	—0.69	—0.51
Ortho-PO^4	—0.60	—0.65
Total P	—0.72*	—0.76*

* Symbols: *, $P < .05$;**, $P < .01$.
+ Degrees of freedom (df) = 7 except for NH^3-N, NO^3+NO^2-N, total N, ortho-PO^4, and total P, where df = 6.

Age, Growth, and Relative Weight

Age and Growth

New annuli were visible on scales of bluegills collected between midwinter and late spring. New annuli first occurred on the outer margins of scales in January 1981 in both SJR-4 (1 of 37 fish sampled) and SJR-6 (9 of 31 fish sampled), and in March at SJR-1 (2 of 8 fish sampled). Annulus formation was completed by April in all reaches except SJR-4 (44 of 45 fish sampled had new annuli), where annulus formation continued through May.

The body-scale relations of 4,862 bluegills were well described by simple linear equations fitted by least squares; r^2 values for the different reaches ranged from 0.82 to 0.97. Intercepts ranged from 16.3 mm at both SJR-3 and SJR-4 to 24.0 mm at Salt Slough. Because the values varied so little, the unweighted mean of all intercepts, 19.0 mm, was used to back calculate total lengths at the end of each year of life; this value compares favorably with the standard value of 20 mm proposed by Carlander (1982).

Young-of-the-year were captured in all reaches; fish $\leq$ 25 mm long entered the catch in June or July. Maximum ages of bluegills captured ranged from 3 yr (i.e., fish in their fourth growing season) at SJR-3 and Salt Slough, to 5 yr at SJR-1 and SJR-2 (Table 6).

In general, growth rates for males and females were similar at all reaches (i.e., there were few significant differences in the mean total lengths attained by males and females after each year of life). However, there were three exceptions: age II females were larger than males in SJR-6 ($t = -2.13$, $df = 38$, $P < .05$) and in MR-2 ($t = -3.29$, $df = 30$, $P < .01$); and age III males were larger than females in SJR-4 ($t = 2.20$, $df = 12$, $P < .05$). These few sexual differences were disregarded in our evaluation of overall growth histories.

The back calculated growth of 1,825 bluegills (sexes combined) ranged from about 39 to 47 mm at annulus I, 72 to 101 mm at annulus II, 89 to 139 mm at annulus III, 145 to 167 mm at annulus IV, and 165 to 168 mm at annulus V (Table 6). Mean lengths attained after each year of life were not significantly different ($P > .05$) among reaches.

Annual growth increments were inversely correlated with fish age ($r = -0.72$, $df = 29$, $P < .01$), indicating that growth rates decreased among older fish. Further analysis showed that fish from populations with rapid growth during the first year of life also grew rapidly during their second year ($r = 0.47$, $df = 29$, $P < .01$); however, growth rates during the third year were not correlated with second year growth ($r = 0.03$, $df = 20$, $P > .05$). Growth in the fourth year was negatively correlated with growth in the third year ($r = -0.68$, $df = 8$, $P < .05$), suggesting that large fish (i.e., fish that grew rapidly during their first three years) grew more slowly than smaller fish of the same age.

Relative Weight

In general, sex-related differences for W_r were negligible. Only 2 of 55 monthly comparisons of W_r values for male and female bluegills were significantly different: females were in slightly better condition (i.e., heavier) than males of similar length at MR-2 in January 1981 ($t = -2.21$, $df = 12$, $P < .05$), and males were in better condition than females at MR-1 in July 1981 ($t = 3.27$, $df = 11$, $P < .01$).

Relative weight was not correlated with length at time of capture ($r = 0.19$, $df = 32$, $P > .05$) or age ($r = 0.16$, $df = 32$, $P > .05$). In addition, even though the mean W_r for different reaches ranged from 96 at SJR-6 to 111 at SJR-2, the differences were not statistically significant (one-way ANOVA, $F_{8,25} = 2.33$, $P > .05$).

Growth, Relative Weight, and Environmental Variables

With two exceptions, physicochemical characteristics (see Table 1 for specific variables) and biological characteristics (C_r and other indices given in Tables 2–3) were not significantly correlated with either growth rate or W_r. The two exceptions were NH_3—N vs. total length of bluegills at age IV ($r = 0.798$, $df = 5$, $P < .05$) and C_r of fish > 100 mm long vs. fish length at age IV ($r = -0.889$, $df = 5$, $P < .01$).

TABLE 6. Summary of Age and Back-calculated Total Lengths of Bluegills. Values are Means ± SD in mm. Calculated from Unweighted Mean Lengths Attained by Individual Year Classes After Each Year of Life.

Reach *	*Sample size*	*Age (years)*				
		I	*II*	*III*	*IV*	*V*
SJR-1	344	39.1 ± 4.0	81.8 ± 17.7	115.0 ± 18.1	145.3 ± 1.6	164.6
SJR-2	152	46.9 ± 3.1	100.5 ± 6.2	130.9 ± 12.9	150.1 ± 14.7	168.4
SJR-3	119	39.6 ± 4.1	72.3 ± 3.0	88.6		
SJR-4	432	44.2 ± 2.7	84.6 ± 10.5	116.4 ± 7.3	167.3	
SJR-5	161	38.6 ± 5.5	86.1 ± 3.6	124.2 ± 18.6	144.9 ± 21.5	
SJR-6	175	43.7 ± 2.9	93.8 ± 13.6	124.4 ± 15.6	164.7	
Salt Slough	13	39.6 ± 9.3	80.8 ± 18.4	96.3 ± 25.0		
MR-1	243	42.0 ± 7.2	78.2 ± 22.1	110.5 ± 18.8	151.4	
MR-2	186	45.5 ± 3.4	97.1 ± 1.9	138.6 ± 8.3	149.1	
Grand mean	1,825	42.1	86.1	116.1	153.3	166.5

* See Figure 1 for names and locations of reaches.

DISCUSSION

There is little doubt that irrigation activities have caused a general deterioration of the aquatic habitat on the San Joaquin Valley floor. Many of the physicochemical differences between upstream and downstream reaches noted in the San Joaquin and Merced rivers—e.g., temperature, conductivity, turbidity, discharge, sediment size composition, total alkalinity, and dissolved nutrients (Table 1 and Saiki 1984)—could influence the occurrence and abundance of stream-dwelling invertebrates (Hynes 1970), and may explain the lower standing crops and diversity of benthic macroinvertebrates at the downstream reaches (Table 2). In the Merced River, Sorenson and Hoffman (1981) attributed upstream to downstream decreases in the abundance (numbers of individuals) and diversity of benthic invertebrates to changes in substrate composition (upstream, the substrate was largely mixed gravel and sand; downstream, fine sand and silt). Studies conducted in other river systems (Dance and Hynes 1980, Welch et al. 1977) have shown that drainage from agricultural lands causes instream environmental modifications—intermittent flows, heavier sediment and nutrient loads, higher summer temperatures, and pesticide contamination—that may reduce the diversity of the macroinvertebrate community, decrease the standing crop, or both.

Less certain is whether environmental changes from irrigation activities have influenced the fish fauna. Food, growth rate, and body condition are three biological characteristics of fish populations that can be affected by changes in the aquatic environment (Lagler, Bardach, and Miller 1962; Bennett 1971; Warren 1971).

Food

Aquatic invertebrates are usually the most important food items in the diets of bluegills. Although small bluegills may feed almost exclusively on planktonic crustacea (Werner 1969; Hall, Cooper, and Werner 1970; Siefert 1972), an inverse relation typically exists between bluegill size and the percentage of microcrustacea in their diet (Hall et al. 1970). In larger bluegills, aquatic insect larvae and other macroinvertebrates typically constitute the primary forage, and flying insects, small fish, fish eggs, and plant material rank second (Goodson 1965, Turner 1966). Keast (1979) stated that bluegills are generalized feeders that forage on individual taxa according to their occurrence in the environment. However, Keast also noted that exceptions occur; for instance, even though oligochaetes are usually abundant in the benthos, they are rarely found even in the stomachs of generalists.

The important role that macroinvertebrates play in the diets of generalized feeders such as the bluegill suggests that major differences in the benthic fauna should be reflected in their food habits. Aquatic insects that were abundant at upstream reaches (e.g., Trichoptera, Ephemeroptera) in the Merced and San Joaquin rivers but scarce or absent downstream (Sorenson and Hoffman 1981; M.K. Saiki, unpub. data) were also important as bluegill foods only at upstream reaches (Figure 4). Longitudinal patterns in the occurrence of benthic taxa also seem to explain the upstream-downstream differences noted in the analysis of food overlaps (Table 4). Perhaps the clearest evidence of association between species composition in the benthos and diets, however, was the significant correlation ($r = 0.85$, $df = 7$, $P < .01$) between benthic diversity (Table 2) and

the diversity of foods eaten (Table 3). These results suggest that the composition of the benthic fauna constrains the variety of foods eaten by bluegills.

Neither the standing crop nor the diversity of benthic invertebrates was correlated with the stomach fullness index (standing crop of benthos vs. C_r, $r = 0.52$, $df = 7$, $P > .05$; benthic $\bar{d}$ vs. C_r, $r = 0.38$, $df = 7$, $P > .05$), suggesting that the total benthic fauna did not limit the amount of food eaten by fish. According to Hall et al. (1970), the ability of bluegills to use zooplankton as food under conditions of high prey (= zooplankton) density could compensate for vicissitudes in benthic production. In downstream reaches, where benthic foods were less abundant (Table 2), bluegills apparently supplemented their diets by foraging on alternate prey (e.g., zooplankton and winged insects), thereby maintaining a stomach fullness index that was not significantly different from that for fish from upstream reaches ($F_{6,77} = 0.98$, $P > .05$).

Age, Growth, and Relative Weight

Scott and Crossman (1973) stated that the maximum age of bluegills appears to be 8–10 yr. However, Carlander (1977) noted that bluegills up to 11 years old have been reported, based on ages determined from scales. Moyle (1976) mentioned that a large bluegill (230 mm) in California is likely to be 8–9 yr. old. Maximum ages of bluegills captured during our study ranged from 3 to 5 yr. (Table 6), indicating relatively short life spans particularly downstream in SJR-3 and Salt Slough.

According to nationwide data summarized by Carlander (1977), bluegills typically attain total lengths of 53 mm by the end of their first year, 95 mm by the second year, 128 mm by the third year, 153 mm by the fourth year, and 173 mm by the fifth year. Moyle (1976) indicated that, in general, growth rates in California lakes and reservoirs are similar to those of bluegills in the midwestern United States, but slower than those of bluegills in the South. Growth of bluegills that we collected from lotic habitats on the San Joaquin Valley floor was generally slower than the average for lentic populations from California (Table 7). To our knowledge, growth histories of populations from other lotic habitats in California have not been published.

Previous attempts to relate growth rates of fishes, including bluegills, to physicochemical and biological characteristics have generally met with only limited success. Laboratory studies (e.g., Lemke 1977, Beitinger and Magnuson 1979) demonstrated a close link between water temperature, the abundance and quality of the food supply, and the growth of bluegills. In the field, average growth has been correlated with total carbonates, total dissolved solids, and plankton abundance (Eddy and Carlander 1940), turbidity (Buck 1956), and pH (Stockinger and Hays 1960, cited by Carlander 1977; Gash and Bass 1973). However, Ridenhour (1960) reported no relation between environmental conditions and either year class success or growth of bluegills in an Iowa lake over an 8-yr. period, except that growth was usually better when aquatic vegetation was more abundant. Ricker (1942) also found no association in several Indiana lakes between bluegill growth and size of lake, average depth, transparency of water, abundance of weeds and bottom food organisms, or abundance of predaceous or competing fish.

Bennett (1971) stated that rapid growth and high body condition (K factor, a measure of "plumpness" similar to W_r) of fish are usually related, although relatively rapid growth seems to be associated in some locations with moderate-

ly low condition at least during part of the year. However, Buck and Thoits (1970) and Cooper, Wagner, and Krantz (1971) indicated that condition factors may be poor indicators of growth in length when measured over only a short period of time. A few studies have reported associations between bluegill condition and environmental variables such as temperature (Proffitt and Benda 1971, McNeeley and Pearson 1974), turbidity and discharge (Proffitt and Benda 1971), and the abundance of food (Morgan 1958, Wohlschlag and Juliano 1959).

In our study, growth rates and W_r of bluegills did not differ significantly among the reaches sampled. In addition, growth and W_r were generally not correlated with physicochemical variables, the standing crop and diversity of benthic macroinvertebrates, or the stomach fullness index and diet diversity.

One reason for the inconsistent results of present and previous attempts to correlate growth with environmental data may be the diversity of variables that can influence growth under field conditions (Carlander 1966). In addition, the relations between many environmental and biological variables may not be linear or even monotonic (Green and Vascotto 1978). Another possibility is that population density, a parameter that we did not measure, may be more important than any other single factor as a regulator of individual growth rates; this relation has been documented by numerous investigators (e.g., Parker 1958, Cooper et al. 1971, Wiener and Hanneman 1982) for bluegill populations in ponds and small lakes. To our knowledge, similar relations between population density and growth of bluegill have not yet been demonstrated for lotic systems such as those we sampled. However, Parsons and Benson (1960, cited by Carlander 1977) reported increased growth of bluegills after fertilization of a portion of the Obed River, Tennessee, which suggests interactions between the food supply and population density.

Carlander (1966, 1977) proposed that environmental factors may control only the maximum biomass of fish that can be supported in a given habitat (i.e., the carrying capacity), and that potential growth of the biomass by recruitment or growth of individuals is determined by the degree to which the biomass is below carrying capacity. If Carlander's hypothesis is correct, relations between environmental factors and growth of bluegills are indirect, and significant correlations are unlikely if the populations under investigation are at or near their carrying capacities.

IMPLICATIONS FOR MANAGEMENT

Despite mounting evidence that lotic environments are greatly modified by return flows and other by-products of irrigated agriculture, the effects of these modifications on fish populations are still poorly understood. Of several bluegill life history characteristics that we measured (i.e., food, growth, and relative weight), only food appeared to be influenced by environmental changes. The considerable flexibility or adaptiveness that characterizes many freshwater fishes (e.g., Larkin 1956, Le Cren 1965), especially bluegills, that allows them to modify their population densities and growth rates probably explains our inability to detect effects on growth and relative weight. However, measurable effects on these characteristics may eventually occur if environmental degradation in the lower San Joaquin River approaches the tolerance limits of this species.

TABLE 7. Comparison of Bluegill Growth in Various California Waters.

Location and source of information	*Sample size*	*Age (years)*						
		I	*II*	*III*	*IV*	*V*	*VI*	*VII*
This study, grand mean *	1,825	42.1	86.1	116.1	153.3	166.5		
Folsom Lake (Tharratt 1966) +	389	35.6	78.7	121.9	177.8	200.7	221.0	
Millerton Lake (Miller 1971) +	231	43.2	78.7	109.2	134.6	160.0		
Cachuma Reservoir (Puckett 1965) *	115	48.3	91.4	134.6	149.9	175.3	208.3	
Lake Havasu (Beland 1954) +	—	50.8	127.0					
El Capitan Reservoir (Fast, Bottroff, and Miller 1982) +	762	54.2	95.8	125.8	147.9	163.1	173.8	180.0
Lower Otay Reservoir (Puckett 1965) *	69	55.9	114.3	152.4	193.0			
Pine Flat Reservoir (Miller 1971) +	204	55.9	121.9	147.3	160.0			
Sutherland Reservoir (La Faunce, Kimsey, and Chadwick 1964) +	1,262	55.9	132.1	185.4				
Felt Lake (Bruns 1958, cited by Carlander 1977) *	—	80	125	155	171			
Clear Lake (Murphy 1951) +	124	104.1	165.1	205.7	226.1	231.1		

+ Fork length (mm).
* Total length (mm).

Although much remains to be learned about how fish populations are affected by irrigated agriculture, alternative farming practices are available or might be devised to lessen potential impacts and perhaps even enhance fish and wildlife habitats. Researchers are currently examining ways to reduce the contaminant load of return flows (e.g., Loehr 1979). In the San Joaquin Valley, construction of a drainage canal has been proposed to collect and dispose of irrigation wastewater directly into the Sacramento-San Joaquin Delta, thereby reducing inputs to the San Joaquin River (Hanson 1982*a*, 1982*b*). The use of return water is also being considered for marsh development (Gilmer et al. 1982) and for aquaculture (Monaco, Brown, and Gall 1981).

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NOTES

AN OBSERVATION OF REPRODUCTIVE BEHAVIOR IN A WILD POPULATION OF AFRICAN CLAWED FROGS, *XENOPUS LAEVIS,* IN CALIFORNIA.

Information on the status of the African clawed frog, *Xenopus laevis,* in California is largely anecdotal (Mahrdt and Knefler 1972, 1973; St. Amant 1975; Branson 1975; Branning 1979; LaRue 1980). Studies are few in number (Munsey 1972; St. Amant, Hoover, and Stewart 1973; McCoid and Fritts 1980 *a*; *b*; B. J. Zacuto, Calif. Fish and Game, unpubl.; Fritts and McCoid, Riverside Co. Fish and Game Comm., unpubl.). This report provides the first observation of reproductive activity of the African clawed frog in the wild in California.

From summer 1974 through spring 1977 I studied populations of the African clawed frog in southern California. Observations on reproductive behavior were made at a pond 1.6 km southwest of Vail Lake, Riverside County (see McCoid and Fritts 1980*b* for a site description). The African clawed frog typically inhabits turbid waters (Picker 1980) and most of my study sites of the African clawed frog in southern California were quite turbid. Possibly because of this, observations of reproductive behavior reported in the literature have been limited to studies made in captivity. The pond in Riverside County was clear and provided a unique opportunity to observe behavior under natural conditions.

I studied the population in Riverside County from April 1975 through March 1977. On 30 March 1976 I first noticed that males had begun calling and began my behavioral observations then. Calling choruses began approximately ½ h before sunset and continued after dark, although an occasional call was heard during the day. The African clawed frogs called from late March through early June, but actual reproduction was not seen until mid-April. Eggs and larvae were collected in this pond between 22 April and 20 May. The estimated peak of calling intensity occurred in April and May.

During the peak calling period, choruses could be heard from 10 to 15 m from the water. The waters' edge could be approached without caution as reproductive activity apparently overroad evasive activity. Ordinarily, during the rest of the year approaches had to be made rather stealthily for any observation. After dark, observations were conducted with the aid of flashlights and these evoked no apparent response. Most African clawed frogs observed were quiescent with only short sporadic movements and rare feeding activity. However, movement close to a male (easily differentiated, as males are smaller than females) by another frog (of either sex) elicited a chase, this being given up in less than a meter if not caught. If capture was effected and a male amplexed another male, release was almost immediate. Picker (1980) reported a male release call which accounts for brevity of male-male encounters. Females responded two different ways when amplexed.

First, the female and male would continue swimming with occasional stops in vegetation. At these stops, their feet would slightly twitch and then pump two to ten times in 2 to 3 s. This sequence was followed by a resting period and repeated (usually in a different clump of vegetation). The longest period of

observation was 10 min for one pair before being lost in vegetation. Bles (1905) reported behavior very similar to this in the laboratory with observed oviposition.

The other response was where the female initiated a rigor stance immediately after being amplexed. Picker (1980) described this as the reaction of a nonresponsive female to a male. Perhaps these females had recently laid eggs and were unable to oviposite. The female would assume a rigid position with her legs extended completely and back slightly arched. A male would continue amplexing a tonic female and swim around with her but generally released her within 1 min. The female would then drift to the bottom and remain rigid from 5 s to 2 min.

Males would respond to movement in front of them. They could easily be enticed to amplex my hand by slowly moving it in front of them under water. At one time a California toad, *Bufo boreas,* was observed to be amplexed by an African clawed frog for in excess of 1 h until I disturbed them.

ACKNOWLEDGMENTS

I thank the Riverside County Fish and Game Commission for partial support of field work. For assistance in the field, I thank D. Ruth, C. Crumly, and H. Snell. T. Fritts provided ample guidance and field assistance.

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PARASITES OF THE SACRAMENTO PERCH, *ARCHOPLITES INTERRUPTUS*

The Sacramento perch, *Archoplites interruptus,* is the only centrarchid native west of the Rocky Mountains. It is endemic to the lower Sacramento-San Joaquin drainage system, Clear Lake, and the Pajaro and Salinas River systems of California. Habitat disruptions and the introduction of competing centrarchids have resulted in a decline in the abundance of the Sacramento perch in its native range (Aceituno and Nicola 1976, Moyle 1976, Vanicek 1980). However, it is not in danger of becoming extinct, as it has been successfully introduced in many other waters.

Murphy (1948); Mathews (1962 and 1965), Moyle, Mathews, and Bonderson (1974); and Aceituno and Vanicek (1976) reported on the life history of the Sacramento perch. However the parasites of this unique species have received little attention. The Sacramento perch was among the species examined in the general fish parasite surveys of northern California waters by Haderlie (1953) and Edwards and Nahhas (1968). This study provides additional information on the parasites of the Sacramento perch by examining the helminth parasites of three populations from different environments and comparing their species composition and infestation rates.

METHODS AND MATERIALS

Sacramento perch used in this study were collected from Lake Greenhaven (Sacramento County), West Valley Lake (Modoc County), and Crowley Lake (Mono County). Lake Greenhaven is a 24-ha artificial lake at an elevation of 15 m, now surrounded by urban development. Water temperatures range from 7°C in winter to 23°C in summer. Fish species present include golden shiner, *Notemigonus crysoleucus;* goldfish, *Carassius auratus;* carp, *Cyprinus carpio;* channel catfish, *Ictalurus punctatus;* mosquitofish, *Gambusia affinis;* Sacramento perch; bluegill, *Lepomis macrochirus;* green sunfish, *L. cyanellus;* white crappie, *Pomoxis annularis;* and largemouth bass, *Micropterus salmoides.*

West Valley Lake is a 388-ha reservoir at an elevation of 1331 m located in the South Pit River drainage system of the Modoc Plateau. It is surrounded by pinon pines, *Pinus monophylla*. Water temperatures range from 5°C in winter to over 20°C in summer. Sacramento perch were introduced in 1972. Other fish species in this lake include rainbow trout, *Salmo gairdneri*; brown trout, *S. trutta;* tui chub, *Gila bicolor*; Sacramento sucker, *Catostomus occidentalis*; Tahoe sucker, C. *tahoensis*; white catfish, *Ictalurus catus*; and brown bullhead, *I. nebulosis.*

Crowley Lake is in the Owens River drainage at an elevation of 2067 m. It is a reservoir of about 2112-ha surrounded by sage brush, *Artemesia tridentata*. Water temperatures range from near 0°C in winter up to 20°C in summer. Sacramento perch were introduced (unauthorized) about 1970. Rainbow and brown trout also occur here.

Of these study lakes, only Lake Greenhaven is located within the native range of the Sacramento perch.

From 17 to 25 Sacramento perch were collected from each lake during the spring and summer of 1979. Fish were collected with gill nets at Lake Greenhaven and West Valley Lake, and with hook and line at Crowley Lake. We immediately placed the fish on ice and transported them to the laboratory where they were dissected immediately, or frozen and dissected later. Each fish was weighed and measured (fork length), and surveyed for ectoparasites before being dissected. Scale samples were taken for age determination. Condition factors were calculated with the equation $C = \frac{W \times 10^5}{L^3}$, where W = weight in grams and L = fork length in millimetres.

Organs (mesentary, digestive tract, liver, gonads) of individual fish were separated into different dishes and carefully teased apart. All parasites were fixed in formal-acetic alcohol (FAA). The specimens were cleared with lactophenol

and mounted wet. Specimens were identified with the aid of Hoffman (1967). R. Toth, Associate Fish Pathologist, California Department of Fish and Game, confirmed our identification of the parasites.

RESULTS AND DISCUSSION

Characteristics of the fish sampled from the three lakes are presented in Table 1. Both sexes and several age groups were represented in all three samples.

TABLE 1. Characteristics of Sacramento Perch from Lake Greenhaven, West Valley Lake, and Crowley Lake, California.

	Average condition factor	*Range in length (mm)*	*Sex: M = Male F = Female U = Unknown*	*Age class*
Lake Greenhaven	1.8	120–150	F: 19	IV–VII[1]
			M: 6	
West Valley Lake	2.0	70–210	U: 7	I (6)
			F: 7	II (4)
			M: 3	III (4)
				IV (2)
				V (1)
Crowley Lake	2.5	180–260	U: 5	II (2)
			F: 7	III (8)
			M: 9	IV (7)
				V (1)

[1] Vanicek, C. D. (1980).

Only one species of parasitic helminth, *Proteocephalus* sp., was found in the Lake Greenhaven fish (Table 2); all 211 specimens were plerocercoids which we could not identify to species, but could be *P. ambloplites*. The gonads were the organ most frequently parasitized (19 fish), followed by the digestive tract (13 fish) and the liver (5 fish). Females had a higher infestation rate (10/fish) than the males (4/fish).

In the West Valley Lake population, the only endoparasite found was *Contracaecum* sp. All were larvae and could not be identified to species, but Haderlie (1953) has identified *Contracaecum spiculigerum* from the Sacramento perch. This parasite occurred in 13 of the 17 fish, and averaged 18 individuals per fish; most occurred in the mesentaries (Table 2). West Valley Lake fish were parasitized externally by *Lernaea* sp.; the infestation rate ranged from one to five.

Two endoparasites were found in Crowley Lake fish: *Contracaecum* sp. and *Posthodiplostomum minimum*. *Contracaecum* sp. was found in the intestines of three fish; the mean infestation rate was one per fish. Ten fish were parasitized with larval *P. minimum*, all of which occurred in the liver, with a mean infestation rate of eight.

Proteocephalus has not previously been reported for the Sacramento perch. Hoffman (1967) reported the following parasites for the Sacramento perch: Trematoda, *Plagioporus serotinus* and *Urocleidus dispar;* Nematoda, *Contracaecum spiculigerum;* Crustacea, *Lernea cyprinace*. Edwards and Nahhas (1968) found only *P. minimum* in Sacramento perch.

TABLE 2. Occurrence of Endoparasites in Sacramento Perch from Lake Greenhaven, West Valley Lake and Crowley Lake.

	Parasite	*No. of infested fish*	*Range*	*Mean infestation rate*	*Total no. parasites*	*Location in fish*
Lake Greenhaven	Cestoidea *Proteocephalus* sp.[1]	23	0–20	9	211	Intestine, liver, gonads
West Valley Lake	Nematoda *Contracaecum* sp.[2]	13	0–24	18	229	Mesenteries, intestine, liver, gonads,
Crowley Lake	Trematoda *Posthodiplostomum minimum*[3]	10	0–20	8	76	liver
	Nematoda *Contracaecum* sp.	2	1–2	1	3	Intestine

[1] Plerocercoids, species identification uncertain, possibly *P. ambloplitis.*
[2] Larval; species identification uncertain, possibly *C. spiculigerum.*
[3] Encysted larvae; *P. minimum* have been found in Sacramento perch from Crowley Lake; personal communication, B. Toth.

The parasite fauna for the three Sacramento perch populations overlapped very little, possibly reflecting the contrasting environments of the lakes. Noble and Noble (1976) pointed out when fish are introduced to new regions their original parasite fauna may be greatly affected by lack of intermediate hosts or by unfavorable water conditions. Within time the host fish may acquire new species of parasites.

The tapeworm *Proteocephalus* in bass causes fibrosis of the gonads that can result in sterility. In small fish the wandering plerocercoids can cause death when they damage vital organs, while in adult fish the plerocercoids produce adhesions which can impair metabolism and reduce egg production (Hoffman 1967). The Lake Greenhaven population is stressed and declining, as evidence by recent reproductive failures, reduced growth, low condition factors, and decreased abundance (Vanicek 1980). The gonads were the most heavily parasitized organ by *Proteocephalus* in the Lake Greenhaven fish, especially the females; perhaps this parasite has contributed to the decline of Sacramento perch at Lake Greenhaven.

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BOOK REVIEW

CHARTGUIDE MEXICO WEST

By Ed Winlund, Jack West, Carolyn West, Charlie Davis, and Dan Gotshall; ChartGuide Ltd., Anaheim, CA; 1983; 76 p; $41.00 (14 by 20 inch, spiral bound).

Everything about *ChartGuide Mexico West* is impressive. The unusual 14 by 20 inch size of this book with its inviting tropical scene on the cover immediately captures the eye. But the best part is inside.

The guide covers the Pacific coast of Mexico from San Diego to Guatamala, including the oceanic islands and the Gulf of California. It begins with the sections "Before You Go" and "Underway", where much advice on dealing with the Mexican authorities, tourist cards, customs, insurance, and the availability of parts is found. "Chart Interpretation" includes the instructions for using the guide. The sections on "Navigation Electronics" and "Radio Communication" are the most complete presentation of those subjects I have seen for any area. Other sections give a good overview on the weather and sea conditions one might find off Mexico.

Most of the book is composed of reproductions of nautical charts illustrating stretches of coastline or islands. Accompanying each chart there is a variety of useful information not often seen on nautical charts, such as land mass shape sketches and pictures of local lighthouses. Many of the islands and areas of particular interest are covered by individual inserts with greater detail. The guide should be of valuable assistance in navigating the Mexican coast, but it should not be, as the authors warn, the only source of navigation information.

Each chart is annotated with information pertinent to the locale, and includes specific chart parameters, tide, assistance, and shoreline descriptions. Anecdotal stories and historical facts are included, as well as the kinds of fishes and shellfish that may be found. All comments referring to a particular chart appear on that chart or on the facing page. There is never any need to flip through pages trying to match text with illustrations and charts.

The last sections list references, including personal comments, charts used, and navigational aides, and a general index to subjects and locations. A nice feature is the inclusion of Spanish translations of technical terms and locations throughout the guide. Such translations may be useful when communicating with non-english speaking Mexicans.

The printing quality of *ChartGuide Mexico West* is clear and crisp which is good as up to six columns of the fine print may be hard for some to read for very long, especially at sea. At $41.00, the price is high, but I think it is a worthwhile investment for anyone traveling to Mexico, especially yachtsmen. Divers and fishermen will find the guide quite useful, too—*Peter L. Haaker*

GUIDELINES FOR MARINE ECOLOGICAL SURVEYS: NEKTON

Prepared by the California Committee on Marine Ecological Survey Standards (C^2MESS); published by the California Sea Grant College Marine Advisory Program; Extension Sea Grant Marine Adivsory Program; University of California, Davis, CA 95616; iv + 12 pp; $2.00

In 1969 the California Committee on Marine Ecological Survey Standards (C^2MESS) began a difficult and much needed task; i.e., organization of guidelines for marine ecological survey methods. They planned a series of publications outlining and summarizing survey methods for biota in a variety of marine habitats. The first publication outlines survey methods for nekton. The fishes and invertebrates comprising this functional group occupy a wide variety of habitats, distributions, abundances, etc. Sampling gear and methods used to survey these organisms are, likewise, highly diverse.

Included are discussions on destructive sampling techniques (i.e., sampling without replacement) using nets, traps, lines, and chemicals and the type of data, both physical and biological, that should be collected during sampling operations.

Use of SCUBA for assessment of nekton populations is also discussed. The most common methods, their application, advantages, and disadvantages are briefly described and summarized in a clear and concise table for easy comparison.

The guidelines also provide a brief discussion of the potential sources of fishery landing data, as well as a short description of pertinent statistical analysis techniques. A glossary of common ecological terms and a list of references are included.

Standardization of techniques in ecological studies is one of the most crucial problems faced by ecologists today. This booklet makes the first step to resolving these problems. While the details of individual sampling programs must be worked out on a case by case basis, the guidelines provide a starting place for all professional biologists and students alike. I eagerly await publication of the rest of the series. At only $2.00 a copy, it is a must for all biologists' libraries.—*Kenneth C. Wilson*

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